

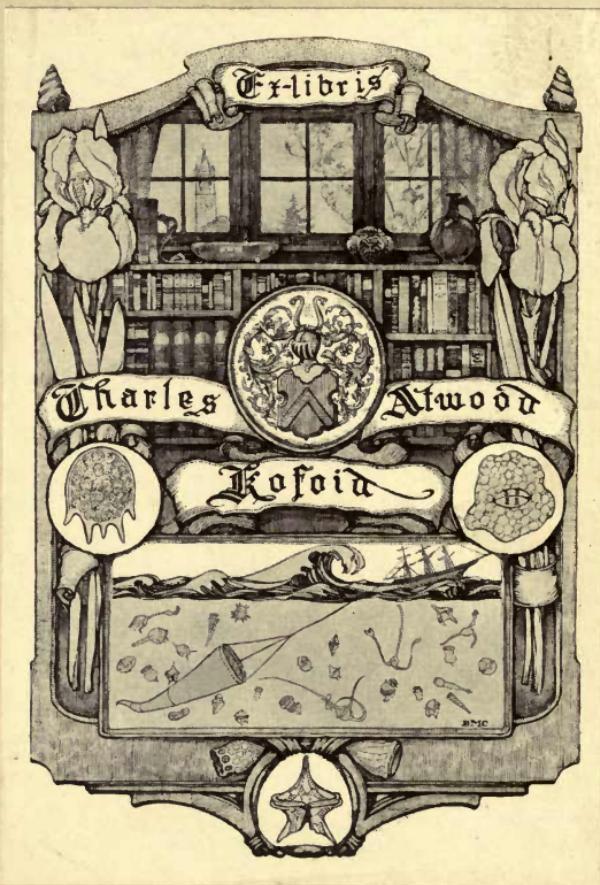
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HOMOLOGIES
OF
THE HUMAN SKELETON
—
H. COOTE.





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THE HOMOLOGIES
OF
THE HUMAN SKELETON.

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THE HOMOLOGIES

OF

THE HUMAN SKELETON.

BY HOLMES COOTE,

FELLOW OF THE ROYAL COLLEGE OF SURGEONS OF ENGLAND,
AND DEMONSTRATOR OF ANATOMY AT ST. BARTHOLOMEW'S HOSPITAL.



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P R E F A C E.

IN the following pages I have endeavoured to give a brief account of the signification of the different bones composing the human skeleton, and to familiarise the mind of the Student in Anatomy with the idea that the whole body is formed of a succession of vertebral segments. The book is unsuited to those who have not previously rendered themselves well versed in elementary Osteology by the careful examination of the different bones, and by the attentive perusal of some of those excellent systems of Anatomy, which, I am happy to say, have been of late years published by our own countrymen, as well as by continental authors. Nor is it put forward as perfect of its kind, the object being simply to direct attention to those discoveries which have been worked out during the last few years, and which, commencing in the skeleton, have been extended over the nervous, the vascular, and the muscular systems. But until the signification of particular bones is more generally understood, the Science of Anatomy must remain as it is, and comprise with the useful much that is dry, unprofitable, and, in many instances, unnecessarily complicated. I must request those who object to the introduction of new terms to suspend their judgment until they

have perused the whole work, and then to consider how far it would have been possible to substitute others in more general use. If those to whom an altered nomenclature in Osteology is so distasteful would denounce the new terms which have been permitted, without remark, to creep year by year into Neurology, they would confer a real benefit upon the Science of Anatomy. It is important to know the elements composing a “transverse process” of a vertebra: upon their proper determination depends the true interpretation of the muscles, arteries, and nerves which surround it; but it is injurious to the cause of Anatomy to multiply names which are applied, without any physiological deduction, to the undefined irregularities of surface noticed upon such an organ as the cerebellum.

The subject being new to Students, I have laid myself open to the charge of repetition by going over parts of the subject twice in different forms, in the hope that facts of importance might be more firmly impressed upon the memory.

I have, in conclusion, to express my thanks to Professor Owen, for the readiness with which he has afforded me every assistance in my attempt to introduce a system, of which he is the founder, into general anatomical instruction.

HOLMES COOTE.

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INTRODUCTION.

WHOMEVER would become a good Anatomist must spare neither time nor labour in the study of Osteology. There is no bone, nor part of a bone, which does not mean more than is implied by the vague and often fanciful name by which it is designated; and a proper recognition of the true signification of such a part leads the mind, by an inductive process of reasoning, both to a correct interpretation of the ends obtained by particular modes of development; and to a just comprehension of the softer structures with which that part is immediately connected.

Nevertheless, Osteology is not a favourite branch of the Science of Anatomy. The great attention paid in the present day to minuteness of anatomical detail has produced in Osteology an extensive assemblage of barren and unconnected facts, which the mind at the outset of its studies is apt to revolt from, or to slur over with ill-concealed distaste.

Thus, a scientific knowledge of the skeleton, of the great cerebrospinal axis, and of the muscles which act on the vertebrae surrounding it, are accomplishments but rarely acquired by the student, although among the simplest and most fundamental truths of Anatomical Science. And until some system can be brought into general use, by which the connection of the different parts may be established, their proper places assigned, and their signification determined, there is but little chance that this subject will be prosecuted in the zealous and comprehensive spirit which it merits.

Such a system is supplied by the study of Homologies; *i. e.* of the relations of corresponding parts; and to Professor Owen is due the merit of having brought it into general notice in this country. My interest in it was excited while attending the Hunterian Lectures in the College of Surgeons, 1846-47; and the idea then struck me that great advantage would result from its introduction into the general course of medical education. Such a system would permit the indication of corresponding parts by the same names, and thus would involve the reconsideration and perhaps the retrenchment of that medley of terms which have been applied to whatever appearances, natural or artificial, happened to catch the eye of the observer: it would, at the same time, draw attention to the signification of different parts; to the objects attained by modifications of their form; to their relative amount of

development; and to their connections. In short, with increased accuracy and simplicity, it would bring with it a larger amount of useful and interesting information than is rendered available to the student of anatomy by any other existing system.

I shall not attempt to apologize for employing the nomenclature of Professor Owen. This work would have been incomprehensible without it; unless, indeed, some far more involved nomenclature, such as that of Oken, of Meckel, or of Spix, had been preferred.

A division of the Animal Kingdom, founded upon the presence or the absence of a vertebral column, was first taught publicly by Lamarck, Professor of Natural History at the Musée in Paris, in the eighth year of the first French Republic, A.D. 1800. "All known animals," says he, "may be distinguished in a remarkable manner,

I. Into Animals with Vertebræ.

II. Into Animals without Vertebræ."

The importance of this distinction, which he claimed to be the first to establish, was speedily recognised by other naturalists, who adopted his views, and introduced his observations into their works, without always acknowledging the source from whence they were derived. Lamarck described the vertebral column as "supporting the head of the animal at its anterior extremity, the pectoral ribs at the sides, and furnished in its entire length with a canal in which is lodged the

pulpy chord, known by the name of the 'Spinal Marrow.' ”

The attention of Anatomists was soon directed to a closer study than had hitherto been made of the different bony segments, the assemblage of which constitutes the framework, or skeleton, upon which this division of the animal kingdom depends. Unfortunately the vertebra selected as a type was taken either from the human subject, or from one of the higher Mammalia, from which cause it happened that the terms which gradually crept into common use were inapplicable as to meaning, and insufficient as to number, when employed in the description of the bone in the lower vertebrata. Even in the Mammalian class new processes were constantly being discovered, which could not be included under any of the commonly-received terms, and hence arose a necessity for the determination of a typical vertebra, and for the substitution, in place of the old, of a new nomenclature, by which every possible element of a bone would be accurately and graphically designated.

Although the signification of a part or organ cannot be properly understood without careful comparison with other parts or organs, by means of which its true place in nature can be determined; yet the first enunciation of the meaning of the cranial bones was more the result of the inspiration of genius, than of that laboured process of reasoning upon observation by which the various details

have been at length worked out. The celebrated Oken, wandering in the south of the Hartz Mountains in August 1806, stumbled upon the blanched, and partially disarticulated skull of a deer. He picked it up, and was examining it, when the idea flashed like lightning across him : "It is a vertebral column!" His forcible and poetical language attracted the attention of anatomists to the subject. That same genius, however, which pointed out to him the great fact, even before he well knew the proofs upon which it rested, led him aside into the mazes of transcendentalism ; for he thought to prove not only the existence of cranial vertebrae, but likewise the repetition in the head of the extremities in modified forms. The malar bones and the upper jaws were compared to the arms ; the two halves of the lower jaws to the legs, and the teeth to the nails. The resemblance of the occipital protuberance to a spinous process ; of the mastoid to a transverse process ; and of the condyles to articulating processes ; was recognised by Dumeril ; Carus believed in the existence of three, and Meckel of four, cranial vertebrae ; but the spirit with which these investigations were carried on, received a check from one who was not more renowned for his extensive researches and original thought, than for the perspicuity and classical beauty of his writings.

The Baron Cuvier* at first inclined to a belief in

* *Sur les ossemens fossiles.*

the existence of these cranial vertebrae; but subsequently, and from no very clear reason, he expressed an opposite opinion, to which he adhered for the rest of his life. “But the fact that the head articulates to the spine by pieces, which resemble those which form the spine itself, constitutes no reason for saying that the head, in its totality, can be regarded as a developed vertebra. None of the parts of the head can be found, either in vestige or in germ, in any vertebra.”*

Geoffroy St. Hilaire, one of the first and most zealous supporters of Scientific Comparative Anatomy in France, maintained, from an early period, the idea of the vertebral structure of the skull; he, however, recognised seven segments, each composed of nine pieces. But at the period when these discussions were going on, no settled opinions had been expressed as to the composition of a typical vertebra, and, so late as 1830, the learned Editor of Hildebrandt’s Anatomy observes, speaking of Geoffroy St. Hilaire, “He carries his idea of a vertebra so far, that he regards the ribs, and the bones of the sternum which lie between the ends of the ribs, as portions of the thoracic vertebrae.”†

Had Oken abstained from the comparison of the upper and lower jaws to the thoracic and pelvic members, and of the teeth to the nails, the cause for which he laboured would have received more nu-

* *Leçons d’Anatomie comparée*, vol. ii., p. 712, 1837.

† *Hildebrandt’s Anatomie*, by Weber, t. ii., p. 133.

merous supporters. His views of the composition of the cranial vertebræ were singularly clear, and remain, in great part, unchanged memorials to the present day of his genius. Every cranial vertebra, he said, consists of three pieces like the dorsal vertebræ; namely, of a body, and of two lateral arches which unite in a spine. In the cranium, the body of the occipital bone and the bodies of the two sphenoids (for there are two of them, even in the head of man,) correspond to the bodies of the dorsal vertebræ. The lateral parts of the cranial vertebræ are formed, for the first vertebra, by the two occipital pieces which support the condyles; for the second vertebra, by the two parietals (*for the temporals do not enter into the construction of the cranium*, they belong to the jaws); for the third vertebra by the two frontals. Lastly, for the face, there is still a vertebra; the body is formed by the vomer, and the spines by the two nasal bones.*

With these materials Professor Owen has followed up the investigation. Having determined the typical vertebra, and designated the elements which compose it by proper and significant names, he has succeeded in unravelling and referring to their proper typical positions the assemblage of bony pieces which constitute the skull. A system so perfect and so elaborately minute as that of Homological Anatomy, not only simplifies by its accuracy the

* *Isis*, i., p. 551, 1820.

study of the structure of the human frame, but it places within the reach of all the advantages derivable from the comparison of the anatomy of man with that of other animals by whom he is surrounded. If there be any one who thinks that such a system can be dispensed with in the study of Comparative Anatomy, I refer him to the best assemblage of anatomical facts which has hitherto been published in a collective form, namely, Cuvier's "Leçons d'Anatomie Comparée." He will, I think, come to the conclusion, that unless employed as a book of reference, it is well nigh useless to any one whose information is not nearly as great, and whose memory is not as tenacious, as that of the accomplished author.

The term *skeleton* ($\sigmaκέλλω$, to dry,) is applied to the assemblage of those parts which, though not extra-vascular, as was once supposed, are yet sufficiently hard and dense to retain, in the dried state, some of their primitive form and character. Thus defined, the skeleton will comprise not only the cranium, the vertebral column, and the extremities, but likewise the general covering of the body, *e. g.* the scales of fish, the hard integument of the crocodile, the bony scales of the armadillo, the horns, hoofs, nails, spines, and hair of animals, the epithelial covering of man. We recognise, therefore, an internal or endo-skeleton, and an external or exo-skeleton; the former being represented by the internal bony framework, the latter by the hard

structures of the integument, under every variety of form and development.

But to these may be added,

I. The bony, cartilaginous or fibrous capsules, which receive the nerves of special sense, and are hence termed sense-capsules ; namely, the olfactory, the optic, and the acoustic. The olfactory sense-capsule is known as the cellular structure of the ethmoid bone ; the optic sense-capsule as the eyeball, which, though permanently fibrous in man, is ossified in birds, reptiles, and in some fish. The acoustic sense-capsule is the petrous part of the temporal bone.

II. Parts of the skeleton which support important viscera, *e. g.* the cartilaginous or bony rings or arches supporting the branchial apparatus in fish, or the respiratory apparatus in warm-blooded animals, and to such is applied the term splanchnic skeleton.

I propose saying but little in the following pages of either the exo-skeleton or the splanchnic skeleton. It is more convenient to reserve their consideration for a future occasion. The sense-capsules are, in most animals, intimately connected with the endo-skeleton, and the two may be described together.

Greatly as the different members of the vertebrate sub-kingdom vary in form and physical characters, they are yet moulded after one common type, and admit, in the systems of organs of which they

are composed, the closest comparison one with another.

An archetype endo-skeleton means that perfect model in which is arranged a succession of the vertebral segments, with their various processes, foramina, and appendages. Although, of course, no true typical vertebrate animal exists, such an image or model is not the less important; because it enables us to recognise, both in the skeletons of different animals as well as in the different segments of the same animal, those points or processes of bone which are strictly speaking homologous. The term "homologue" is thus defined by Professor Owen:—"The same organ in different animals, under every variety of form and function." But we use the term "analogue" to express a part or organ in one animal, which has the same functions as another part or organ in a different animal. The two terms have very different meanings, as the following illustrations will exemplify: The wings of a bird and the fore-limbs of the lion are strictly homologous parts, but their functions are not analogous. They are homologous, because composed of essentially similar structures, namely, humerus, radius and ulna, carpus, metacarpus, and phalanges, surrounded by muscles for flexion, extension, supination, and pronation, &c.; but they are not analogous, because the wings are employed in raising and sustaining the bird in the atmosphere, and the fore-limbs of the lion are constructed chiefly for seizing, holding, and

tearing its prey. The shark supports itself in the rarer strata of the water by means of slow, yet powerful, strokes of its muscular tail ; the eagle and the hawk do the same with their wings. These two parts, then, wings and tail, perform analogous functions, *i. e.* both are organs of propulsion ; but they are not in themselves homologous, because the pectoral fin, and not the tail, is the repetition of the wing of the bird.

“ Homologous parts are always indeed analogous parts in one sense, inasmuch as, being repetitions of the same parts of the body, they bear in that respect the same relation to different animals. But homologous parts may be, and often are, also analogous parts in a fuller sense, namely, as performing the same functions: thus, the fin or pectoral limb of the porpoise is homologous with that of a fish, inasmuch as it is composed of the same or answerable parts; and they are the analogues of each other, inasmuch as they have the same relation of sub serviency to swimming. So, likewise, the pectoral fin of the flying-fish is analogous to the wing of the bird, but unlike the wing of the dragon (*Draco volans*), it is also homologous with it.*

“ Relations of homology are of three kinds: the first is that above defined, viz. the correspondence of a part or organ, determined by its relative position and connexions, with a part or organ in a different animal; the determination of which homology indi-

* On the Homologies of the Vertebrate Skeleton, vol. i., p. 7.

cates that such animals are constructed on a common type: when, for example, the correspondence of the basilar process of the human occipital bone with the distinct bone called 'basi-occipital,' in a fish or crocodile is shewn, the special homology of that process is determined.

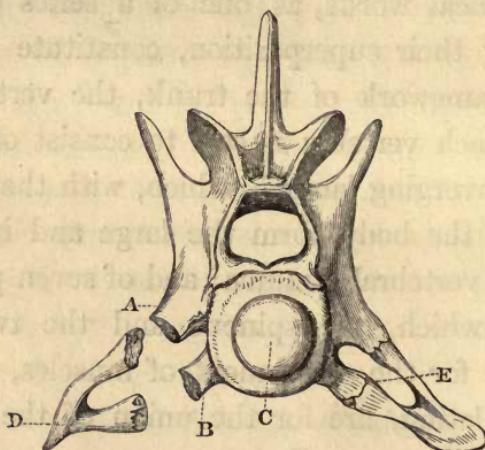
"A higher relation of homology is that in which a part, or series of parts, stands to the fundamental or general type, and its enunciation involves and implies a knowledge of the type on which a natural group of animals, the vertebrate for example, is constructed. Thus, when the basilar process of the human occipital bone is determined to be the 'centrum' or 'body' of the last cranial vertebra, its general homology is enunciated.

"If it be admitted that the general type of the vertebrate endo-skeleton is rightly represented by the idea of a series of essentially similar segments succeeding each other longitudinally from one end of the body to the other, such segments being for the most part composed of pieces similar in number and arrangement, and though sometimes extremely modified for special functions, yet never so as wholly to mask their typical character; then any given part of one segment may be reproduced in the skeletons of different species, and this kind of repetition or representative relation in the segments of the same skeleton is called '*Serial Homology*.' As, however, the parts can be namesakes only in a general sense, as centrums, neurapophyses, ribs,

&c.; and since they must be distinguished by different special names according to their particular modifications in the same skeleton, as *e. g.* mandible, coracoid, pubis, &c., such serially related or repeated parts are called homotypes."

What is a Vertebra? It is commonly described, in anatomical works, as one of a series of bones, which, by their superposition, constitute the solid central framework of the trunk, the vertebral column. Each vertebra is said to consist of a body, of two converging laminæ, which, with the posterior surface of the body, form the large and irregularly triangular vertebral foramen; and of seven processes, three of which, the spinous and the two transverse, are for the attachment of muscles, and four, the articulating, are for the union of the vertebræ one with another. But a cursory glance at the vertebral column will convince us of the insufficiency of this description. The cervical vertebræ, apparently unlike the rest, present, on either side, a foramen for the vertebral artery and vein, in the base of the so-called transverse process. The transverse process in these vertebræ is evidently formed by two roots, of which one, posterior, arises from between the articulating processes; and the other, anterior, from the body of the vertebræ. The latter, generally unnoticed, must either be a part which disappears altogether from the composition of the vertebræ of other regions; or else it must be a rudimentary rib. If it be a distinct element of a

vertebra, it is surely as deserving of a name as any other process or eminence. If it be a rib, then the dorsal ribs must likewise be admitted to form parts of their corresponding vertebrae. Its true nature may be at once seen by examining the cervical vertebra of the crocodile, one of a class of animals whose



bones remain distinct throughout the greater period of their existence. The "transverse process" of a cervical vertebra in the crocodile consists of two processes; one (A), the diapophysis, which arises from between the articulating processes; a second, (B), the parapophysis, which arises from the body (C); and the two support a rib (D), elongated longitudinally to give strength to the extremely movable neck. Between the diapophysis, the parapophysis, and the rib, (the pleurapophysis) there is a foramen (E) for the vertebral artery and vein.

We find in the human cervical vertebra the diapophysis, the parapophysis, and the rib, firmly

coalesced one with another, and with the rest of the bone, and concave superiorly to receive the cervical nerves as they emerge from the intervertebral foramina. But if the cervical ribs form part of a vertebra, so also must the thoracic ribs, though united by a complete joint, and in most instances somewhat displaced, so as to be connected with the bodies or centra of two contiguous vertebrae, and with the intervening fibro-cartilage. Arching forwards, and uniting with the costal cartilages and with the sternum, they form upon the ventral surface of the body a canal similar to that formed upon the dorsal surface by the laminæ and the spinous processes. As in the latter is contained the spinal cord or the myelon, so in the former is lodged the heart, with the large pulmonary and systemic vessels, and the lungs, offshoots of the vascular system.

The body, then, of a vertebra may be described as a centre, around which are four arches, each including a foramen. The posterior, or dorsal foramen, commonly called "vertebral," exists in all human vertebrae, except the coccygeal, and is expanded at the anterior extremity of the trunk into a cranium, which surrounds and protects the assemblage of ganglia constituting the encephalon. The circle of bones which surrounds this foramen is called the neural* arch. The inferior arch is found only in par-

* *Neural* arch, derived from *νεῦρον*, nerve—so called, because it contains the cerebro-spinal axis.

ticular regions of the human skeleton; namely, the cranium, the thorax, and the pelvis: the ring of bone by which it is formed is incomplete in the neck, the abdomen, and lower part of the sacrum; but in animals supplied with long tails, *e.g.* the kangaroo, the ferret, the beaver, or some of the monkey tribe, the coccygeal vertebrae are furnished with an inferior arch of bone, for the protection of the long caudal artery. This inferior ring of bone, whether at the chest, the coccyx, or elsewhere, is termed the “haemal arch.”*

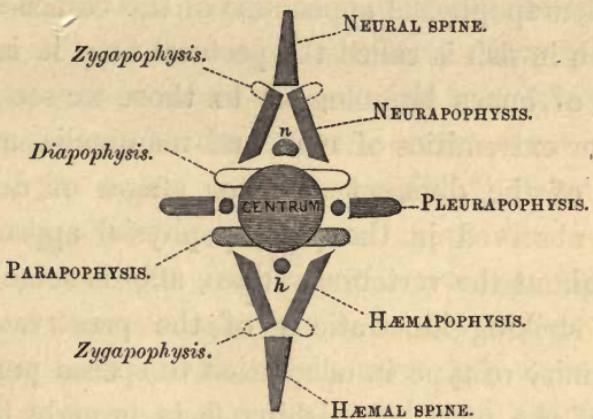
The lateral foramina for the vertebral arteries exist only in the cervical region, where the human vertebrae are supplied with two transverse processes on either side, the diapophysis and the parapophysis.† The absence of the parapophysis in other regions not only does away with the lateral canals, but gives to the bodies of the vertebrae, or the centra, a prominent convex appearance very different from the flat surface presented anteriorly by the cervical vertebrae.

With the following diagram illustrating a typical vertebra, is given Professor Owen's definition of

* *Hæmal* arch, derived from *αἷμα*, blood, because it surrounds the great blood-vessels.

† Diapophysis, parapophysis—outstanding processes. The prepositions *διὰ*, through, and *παρὰ*, from, as applied to these processes, have no meaning but that of indicating attachment to some centrum or base. Any term expressive of a “transverse” direction would be inapplicable, as both dia and parapophyses often become vertical.

such a bone, and the names which he has applied to its component parts. "I define a vertebra as one of those segments of the endo-skeleton which constitute the axis of the body and the protecting canals of the nervous and vascular trunks: such a segment may also support diverging appendages. Exclusive of these, in its typical completeness, it consists of the following elements and parts.



[After Owen.]

" The names printed in roman type signify those parts, which, being usually developed from distinct and independent centres, I have termed 'autogenous' elements. The italics denote the parts more properly called processes, which shoot out as continuations from some of the preceding elements, and are termed 'exogenous,' e. g. the diapophyses, or upper transverse processes, and the 'zygapophyses' or 'articular processes' of Human Anatomy."*

The simplest instance of a vertebral appendage is

* On the Homologies of the vertebrate skeleton, p. 81.

seen in that flat process in the skeleton of birds, which, coalesced with the posterior border of the ribs, extends backwards and upwards, and overlaps the exterior of the rib immediately preceding it. From its costal attachments, it is called 'pleurapophysial,' to distinguish it from a second appendage, attached in certain regions of the body to the hæmapophysis, and hence called 'hæmapophysial.' The pleurapophysial appendage of the coraco-scapular arch in fish is called the pectoral fin: it is composed of bones homologous to those we see in the anterior extremities of man and mammalia, and the study of the different steps or stages of development observed in the pleurapophysial appendages, throughout the vertebrate series, affords some of the most striking illustrations of the preservation of uniformity of type in adaptation to special purposes. One of the most astonishing facts brought to light by the study of homologies is, the occasional mutation of position, or of connexions of the vertebral elements. For special purposes, a particular part or segment of a vertebra is removed from its typical seat to some other region of the trunk, where it is maintained *in situ* by muscular or bony attachments. Its degree of development depends not upon the degree of development of the parent vertebra, but upon its own teleological importance, upon the number of muscles to which it affords attachment, or upon its office as an organ of locomotion or prehension. The hæmal arch of the occipital ver-

tebra, which supports the pectoral extremity, maintains its typical position in fish, at the junction of the head with the trunk, where the organs of respiration and of circulation are collected. The pectoral fin is placed in that position where it can act most favourably as an organ of locomotion. But in birds, who, from the immobility of the dorsal and sacral vertebræ, require a long and flexible neck, it is obvious that the maintenance of the typical attachments of the hæmal arch of the occiput, or the scapulæ and coracoid bones, with the highly-developed appendages forming the wings, would be incompatible with the powers of flight. The hæmal arch, then, is removed to the upper dorsal region, where the weight of the trunk is greatest; the bones become flattened and broad, to afford insertion to muscles; and the cylindrical pleurapophysis, or rib, becomes the scapula, which, sabre-shaped in birds, is developed into a triangular plate in man and mammalia.

The clavicles belong to the atlas: the hæmal spine, by which they should be united, is represented by the small tubercle which projects from the anterior border of its arch. In many animals, *e. g.* the cat, the clavicles are reduced to mere lines of bone, which are loosely imbedded in the subcutaneous tissues of the neck; but in man they are strong bony cylinders, which throw out the shoulders to some distance from the trunk, that the sphere of movement of the upper extremities may be the more free and extensive. No other animal

enjoys, in a like degree, such perfect liberation of the pectoral extremity from the office of supporting the weight of the body in progression. Man alone, by reason of his upright posture, is enabled to employ his hands in the perfection of those various arts by which this once wild and rugged earth has been cultivated ; and both the fruits which it bears upon the soil and the treasures which lie concealed under its crust are made subservient to his wants and his enjoyment.

An accurate enumeration of the different pieces which constitute the human skeleton is not so easy a task as might first appear ; for bones that were distinct in the foetus coalesce with age, whilst others, as the first teeth, last for a time, and then permanently disappear.

Weber reckons 217 bones, namely :—

27 of the head,

58 of the trunk,

132 of the upper and lower extremities ;

and if to these be added

32 teeth,

5 bones of the tongue, and

2 orbicular bones between the malleus and incus, the number amounts to 256.

But in this calculation the occipital and sphenoid bones are counted as one piece, under the name of os spheno-occipitale. The temporal bone, formed by the confluence of five distinct elements, is reckoned also as a single bone. The five sacral ver-

tebræ and the four or five coccygeal vertebrae are enumerated only as two pieces, under the titles of sacrum and coccyx. The ribs and the sternum are described as unconnected with the dorsal vertebrae. Each os innominatum, though composed of ilium, ischium, and pubis, is called a single bone. The difficulty in determining what constitutes a bone accounts for the great difference in the calculations made by the most accurate observers. Meckel reckons 253 bones, and Soemmering 260. Mr. Quain makes the number 197; but he omits the ossicula auditus, the teeth, the os hyoides with its appendages, and the sesamoid bones, as "either accessories or connected with special organs." Adherence to the different centres of ossification in the foetus does not render the task more easy. For, in the first place, the process of ossification in man is not complete until between the twentieth and thirtieth year; and during the whole of that period pieces, originally distinct, are undergoing a blending or coalescence with others. In the second place, an exogenous spine or process, an integral part of a single bone, may be formed by an ossifying centre, developed in some part of the primitive cartilaginous basis.

That these points may be satisfactorily elucidated, it becomes necessary clearly to understand the type upon which a vertebrate animal is formed; we are thence led rightly to understand the signification of the different bones, whether simple or compound, which enter into the composition of the skeleton;

to separate those which have become confluent, and to refer to their proper segment, or system, those which have undergone modifications, or been subject to displacement.

It is far more important to know that ten vertebræ are concerned in the formation of the pelvis and coccyx, than that this Anatomist counted 260, and that one 197 bones in the entire skeleton. It is not the less necessary to recognise the stunted abdominal ribs, than their long and movable representatives in the thorax. The number of vertebræ of which a vertebrate animal is composed may be easily ascertained. In man there are 37 or 38, namely :—

4 or 5 coccygeal,
5 sacral,
5 lumbar,
12 dorsal,
7 cervical,
4 cranial,

37 or 38.

By referring the segments to one common type, we may ascertain the number of elements of which each is composed, and then, by adding the aggregate amount of bones which form the four extremities, we shall make some approach to a correct estimate of the whole. But difficulties beset us in the outset. The typical number of the carpal bones is ten, and not eight. The os scaphoides and the

os unciforme are each composed of two distinct bones. The os calcis in the tarsus represents the os cuneiforme and os pisiforme. In the enumeration of the bones how are we to count these compound pieces?

In this calculation, however, other bones are omitted altogether, being unconnected either with vertebræ or with their appendages. Such are the turbinate bones, the cornua sphenoidalia, the ethmoidal cells, the primitively distinct petrosal bones, the lacrymal bones, &c. Of these, some receive the terminal filaments of the nerves of special sense; others are connected with the common covering of the body, and belong to the dermal skeleton. The thyroid cartilage and the rings of the trachea have an equal right with the os hyoides to be included in the present survey, under the division of the splanchnic skeleton; for the deposit of the amorphous and granular phosphate of lime in a cartilaginous and organized matrix is not a step towards perfect development, but is rather an adaptation of the ingredients to special purposes. The elastic cartilaginous skeleton of the shark is quite as highly organized and as complete as is the osseous skeleton of man.

Until the archetype, then, has been determined, it is useless to attempt accurately to ascertain either the number of the parts which should be included in the skeleton, or the nature of the elements of which each part is composed.

The want of accuracy in the application of names has led to many evils. It has deterred the student from extending his observations beyond the narrow sphere of human anatomy ; for how could he, whose memory was oppressed by the dry details contained in a dissecting manual, hope, with advantage, to commence the study of the structure of other animals, whose component parts had been described from other quarters, or in other countries, under names which had no resemblance to those with which he was familiar ? And yet the two master-spirits of their day, John Hunter and Cuvier, saw well, and taught that a correct knowledge of the human frame could be gained only by comparing the organism of man with that of the other created beings by which he is surrounded. They differed in the course which they pursued in one respect, namely, that whilst Cuvier commenced with man as the most perfect animal, and descended thence step by step to those less highly organized, John Hunter started from the simplest forms, and traced the gradual adaptation or development of parts to meet the exigencies to which an animal in its higher vocation was exposed.

THE HUMAN SKELETON

is composed of thirty-seven or thirty-eight vertebræ, and of appendages, which include the upper and lower extremities.

There are 4 cranial vertebræ; the nasal; the frontal; the parietal; the occipital,

- 7 cervical vertebræ,
- 12 dorsal vertebræ,
- 5 lumbar vertebræ,
- 5 sacral vertebræ,
- 4 or 5 coccygeal vertebræ.

The number of the cranial and of the cervical vertebræ remain the same, with but two exceptions,* throughout the mammalian class; but the number of the dorsal vertebræ, or of those vertebræ from which long pleurapophyses, or ribs, arch forwards, varies in different animals, so as to give as much support to the viscera as is compatible with the proper mobility of the trunk. In most Carnivora the number of the dorsal and lumbar vertebræ united is the same, although the number of the movable ribs, and consequently of the dorsal vertebræ, varies considerably, as the following examples will shew.

* The three-toed sloth has nine cervical vertebræ, and the manati has but six.

	Dorsal vertebræ.	Lumbar vertebræ.	Total.
Black Bear of America }	14	6	20
Dog . .	13	7	20
Panther . .	13	7	20
Spotted Hyæna	15	5	20
Glutton . .	15	5	20

As it is for many reasons more convenient to reserve the account of the cranial vertebræ for subsequent consideration, we will commence with the description of the cervical vertebræ.

Cervical Vertebræ, 7.

The centrum, or body, is elongated transversely, and of oval form: it is thick anteriorly, where a process, or spine (hæmal), dips downwards in front of the vertebra which succeeds it; the upper surface is slightly concave from side to side; the lower surface is convex; the posterior surface, bounding anteriorly the vertebral or neural canal, is smooth and flat.

The transverse process includes a parapophysis, a diapophysis, and a small pleurapophysis, or rib. The parapophysis is a small pedicle which arises from the lateral surface of the centrum; the diapophysis arises between and a little in front of the zygapophyses, or articulating processes. The interval between the two is completed into a foramen (vertebral) by the pleurapophysis, which is coalesced with the extremities of the dia and parapophyses,

and is hollowed out into a groove, to receive the cervical nerve as it emerges from the intervertebral foramen : the extremity of this groove gives to the transverse process a bifid appearance. If so much of the transverse process of a cervical vertebra be sawn off as will lay open the vertebral foramen, the pleurapophysial element will be separated from the dia and parapophyses, with which it is united. The hæmal arch is incomplete.

The neurapophyses commence by a constricted portion, the pedicle, which inclines outwards, and then becoming broader, bends inwards, to unite with its fellow at the neural spine, which, in the cervical region, is directed obliquely backwards and downwards, and retains in the bifid extremity the mark of its formation from two lateral halves. At the junction of the pedicle with the flatter portion of the neurapophysis are situated the zygapophyses and the root of the diapophysis. This spot is of interest, as being one of the primitive points of ossification of a vertebra. The deposit of bone extends in three directions, forwards and inwards, towards the centrum, where it unites with a central nucleus of bone ; backwards and inwards, along the cartilaginous neurapophysis to the neural spine ; and outwards, towards the cartilaginous pleurapophysis, to form the diapophysis. The parapophysis is a growth from the centrum.

The neural canal is triangular, and large in proportion to the segments of the nervous centre which

it contains. The zygapophyses, or articulating processes, are oblique, the upper pair looking upwards and backwards, the lower pair downwards and forwards.

The neural canal contains the myelon (spinal chord) and its membranes, and conveys the accessory nerves to the interior of the cranium.

The lateral canals contain the vertebral artery, which enters the skull by the foramen magnum, or the neural canal of the occipital bone; the vertebral vein, which commences on the outer and back part of the head; and some branches of the sympathetic nerve.

The first, second, and seventh cervical vertebræ possess characters which require particular description.

The first, named the atlas, from its supporting the expanded globe-like cranium, is a ring of bone placed horizontally so as to rotate freely upon the second cervical vertebra, or the axis. The lateral masses, which terminate above and below in the zygapophyses, seem to divide the ring of the atlas into an anterior and a posterior arch.

The anterior arch, part of the centrum, is hollowed out posteriorly, where there is a smooth articulating surface, to receive the odontoid process of the axis. Upon the front of the thin arch-shaped portion of the centrum is a tubercle, the hæmal spine, here rudimentary, and coalesced with the centrum. Were the hæmal spine removed from the centrum, and

the hæmal arch completed by its proper bones, then the clavicles would leave their connection with the coraco-scapular arch, and extend as hæmapophyses from the centrum of the atlas to the hæmal spine, or anterior tubercle.

The centrum is constricted vertically in the mesial line, to allow of the free downward movement of the head, in nodding, bowing, &c.

The transverse processes are long, and are composed of a parapophysis, directed obliquely downwards and outwards, which arises from the thick lateral masses of the centrum between the zygapophyses; of a diapophysis more horizontal, which arises from the neural arch; and of a rudimentary pleurapophysis, coalesced with the distal extremities of the preceding, and completing the foramen for the vertebral artery. This pleurapophysis is not grooved to support the first pair of cervical nerves, because they escape from the neural canal behind the zygapophyses, and behind the whole transverse process; but it is a smooth flattened tubercle, the anterior surface of which is directed obliquely forwards and upwards.

The transverse processes of the atlas are long, to afford leverage to the superior and inferior oblique muscles of the head.

The neurapophyses are thin and flat, and arch backwards, to terminate in a small posterior tubercle, the neural spine.

The upper pair of zygapophyses, hollowed out to

receive the condyles of the occipital bone, are directed upwards and inwards, and converge somewhat anteriorly. At their junction with the root of the neurapophyses is a groove, which receives the vertebral artery previous to its entrance into the cranium, and which serves to transmit the first pair of cervical nerves. The lower pair of zygapophyses are nearly horizontal, and are flat, to allow of the rotatory movement of the atlas upon the axis. Upon the inner surface of the thick lateral portions of the atlas, just above the lower pair of zygapophyses, is a rough tubercle, which gives attachment to the transverse ligament. The ring of the atlas is divided by this ligament into an anterior and a posterior part; the anterior, the smaller, contains the odontoid process; the posterior, and larger, gives passage to the myelon, or spinal chord.

The second cervical vertebra, the axis, so called because the atlas rotates upon it as upon a pivot, is thicker and stronger than the atlas, but the transverse processes are not nearly so long and prominent. The under surface of the centrum, which articulates with the third cervical vertebra, is flat from side to side, but has a concave appearance from before backwards, in consequence of the prolongation downwards of a tongue of bone, as in the other cervical vertebrae. The front surface presents a prominent ridge, the hæmal spine, which separates two concavities from whence arise the oblique portions of the longus colli muscle. The posterior sur-

face is rough and flat ; it affords attachment to ligaments, and presents several large foramina, which contain, in the fresh state, veins from the interior of the bone.

The upper surface of the centrum seems prolonged into that prominent bony cylinder, the odontoid process, which fits into the atlas, so as to occupy the position of the centrum. In front there is a smooth oval surface, in the fresh state crusted by cartilage, which articulates with the smooth surface upon the concavity of the centrum of the atlas. Behind there is a narrow constricted portion, also smooth, and covered by cartilage, which seems to divide the odontoid process into a head and neck, and which lodges the transverse ligament of the atlas. The apex of the odontoid process is flattened, and rough, for the attachment of the oblique ligaments.

The transverse processes support the upper pair of zygapophyses, which, of large size, round, and nearly horizontal, lie on either side of the odontoid process, in front of the inferior pair of zygapophyses. The parapophysis is directed obliquely downwards and outwards ; the diapophysis, reduced to a thin line of bone, inclines forwards ; they both terminate in a small rounded tubercle, the rudimentary pleurapophysis, which extends but a few lines beyond the outer border of the corresponding inferior zygapophysis. The foramen for the vertebral artery is formed by the coalescence of the dia and parapo-

physes, with the rudimentary pleurapophysis, or rib, and is directed upwards and outwards.

The inferior zygapophyses, smaller than the superior, and of oval form, are directed obliquely downwards and forwards. The neurapophyses, broad and strong, incline backwards and inwards, to unite and form a prominent neural spine, which terminates below in a bifid extremity, the trace of its early separation into two lateral halves. On either side of its base is a depression, to which is attached part of the semispinalis colli muscle. The neural canal is smaller than that of the atlas, and is of oval form. The long neural spine of the ~~atlas~~ gives origin to the obliqui capitis inferiores muscles, which, inclining upwards and outwards, are inserted into the equally prominent transverse processes of the ~~atlas~~. From the latter points of bone arise the obliqui capitis superiores muscles.

The neural spine of the ~~atlas~~ and the transverse processes of the axis, which do not give attachment to muscles of great power and importance, are arrested in growth as tubercles of bone. The small oblique muscles of the head, with the levers to which they are attached, undergo their highest degree of development in those animals which, supplied with fore-limbs fashioned for seizing and holding their prey, employ the mouth, armed with strong canine and incisor teeth, for tearing it to pieces.

The seventh cervical vertebra approaches in some of its characters those of the dorsal region. The

direction of the inferior pair of zygapophyses is more vertical ; the parapophysis is thin, and sometimes imperfect, but it combines with the diapophysis to support a pleurapophysis, which, often of considerable length, bears a resemblance, not to be mistaken, to the movable ribs of the thorax. The groove for the spinal nerve is very shallow. The neural spine is long, and surmounted by a tubercle. It can be felt under the integument, and gives origin to the ligamentum nuchæ, which covers the neural spines of the cervical vertebræ which precede it.

Dorsal Vertebræ, 12,

The dorsal vertebræ are twelve in number : the neural canal, formed as in the cervical region, contains the corresponding segments of the myelon ; the hæmal canal is completed by the ribs (pleurapophyses), the costal cartilages (hæmapophyses), and the sternum (the coalesced and expanded hæmal spines) : it contains that great varicose enlargement of the vascular system, the heart, with its offshoots, the lungs, and the main arterial and venous trunks. There are no lateral canals, as were seen in the neck, for the vertebral arteries ; the parapophyses, or the anterior transverse processes are not developed, and the pleurapophyses, no longer confluent with other parts of the vertebræ, are movable bones, somewhat displaced, so as to articulate by a round head with two conti-

guous vertebræ, and with their intervening fibrocartilage; and by a tubercle with the extremity of the diapophysis of the superior of the two vertebræ. Instances of this displacement of the vertebral elements are not uncommon. They may be seen in the connection of the hæmal arches with the caudal vertebræ in the kangaroo, the ferret, &c.; and in the disposition of the vertebral segments of the cranium, where the elements undergo much greater change and variety of form and relation than in other parts of the body.

The centra of the dorsal vertebræ, constricted in the middle, are more convex and prominent anteriorly than those of the cervical or of the lumbar regions. And this prominence is the more marked in consequence of the absence of the parapophyses, which, springing from the sides of the centra, give to the cervical vertebræ their flat appearance when viewed from the front in the articulated spinal column.

The diapophyses incline outwards and backwards from between the zygapophyses: they are longer than those of the cervical vertebræ, but they decrease in length from above downwards. About the ninth dorsal vertebra the diapophyses effloresce into three points, which become more strongly marked in the succeeding vertebræ, as far down as the third lumbar, where the diapophyses usually resume their single rounded extremity. The extreme point of the three is attached by ligament

to the tubercle of the pleurapophysis, and is to be regarded as the extremity of the diapophysis: that nearest the neural spine, is an exogenous process, the epi-diapophysis. In many quadrupeds this is so far elongated as to reach the level of the neural spine, when the vertebral column (viewed posteriorly) presents three rows of spines instead of one. In the armadillo these lateral spines afford great support to the heavy armour which rests upon the back.

The process of bone between the two preceding, projects downwards, and terminates in a point. Traces of it may be seen, in well marked skeletons, as far as the fourth or even the fifth lumbar vertebra, but it gradually becomes fainter. It is called the metapophysis,* and its relations may be better studied in the skeleton of the monkey than of man. We there find it a long depending bony process, which passes down to the outer side of the superior articulating process of the vertebra below, which is thus wedged in between two bony plates, viz.: the articulating process, or zygapophysis, to which it is properly attached, internally, and the long depending metapophysis, externally. The articulations of the vertebræ are rendered more secure by these means; but though they readily allow the spine to curve backwards and forwards, as in the spring of the lion or cat, they do not permit with equal readiness the lateral swaying movement of the

* Metapophysis, *μετά*, with, along with.

trunk, so necessary to maintain the balance in progression in the erect posture. The long metapophysis of the monkey serves to limit, and interfere with this movement. In man, on the other hand, the process is short and stunted; but in both it affords attachment to that assemblage of muscular and tendinous slips, known as the longissimus dorsi muscle, part of the common erector spinæ, which extends along the whole length of the vertebral column.

Lumbar Vertebræ, 5.

The lumbar vertebræ, five in number, are broad and solid, for the support of the superincumbent weight. The different elements which enter into their composition are less distinct than in the dorsal vertebræ, in consequence of the coalescence of the pleurapophyses with the centra and with the dia-
pophyses, and of the altered direction of the zygapophyses. The centra are broad and convex, though flattened anteriorly; the neurapophysial pedicles are constricted; the neural spines are compressed and quadrilateral. The process of bone, commonly called transverse, is the pleurapophysis, or abdominal rib; and the nodule of bone lying to the outer side of the superior zygapophyses, and called by Cruveilhier "apophysary element," is the diapophysis, which still exhibits traces of that tripartite efflorescence of the apex observed in the lower dorsal region. If, in the articulated skeleton, the eye be

carried along the dorsal diapophyses, or transverse processes, the relation of this element to the pleurapophysis will be seen without difficulty in the whole region. If it be wished to separate the whole lumbar, or abdominal rib, the misnamed transverse process must be sawn off from the diapophysis in such a way as to resemble the last dorsal pleurapophysis ; in other words, a process of bone must be removed down to the sides of the lumbar centrum. We may then notice, in the remaining diapophysis, those three points above mentioned.

Sacral Vertebræ, 5.

The five vertebræ composing the sacrum form a triangular and anteriorly concave piece, perforated on either side, both in front and behind, by four foramina, for the transmission of the anterior and posterior branches of the sacral nerves. The centra become smaller from above downwards. In the three superior vertebræ the neural arch is complete ; in the two inferior, the neurapophyses are unconnected by a spine, and the canal is open behind.

In front each sacral vertebra presents a rudimentary pleurapophysis, coalesced with the centrum and the diapophysis precisely as has been described in the lumbar vertebræ. These pleurapophyses are distinct bones in the foetus, at which time it can be seen that the ilium belongs to one vertebra only, namely, the first sacral, the haemal arch of which it assists in forming. The serial homology of the

ilium and pubis may be explained, according to Professor Owen,* in either of two ways. Either the ilium is the hæmapophysis, and the pubis the hæmal spine; or the pleurapophysial element of the sacrum with the ilium forms a divided and articulated rib, and the pubis represents the hæmapophysis, the hæmal spine being reduced to the cartilaginous structure in the pubic symphysis.

The ischium constitutes the hæmapophysis of the second sacral vertebra, and may be excluded from the consideration of the hæmal arch of the first sacral vertebra.

In the human skeleton the highly-developed condition of the iliac bones obscures, in some degree, their typical connections; but if the pelvis of the lower vertebrata be examined, these points become far more easily ascertained. The pleurapophysial character of the ilium and ischium, with the mode of formation of the obturator foramen, primitively an intercostal space, is well seen in the skeleton of birds, or of chelonian reptiles, in whom the muscles which arise from the pelvis have no need of the broad and extensive surface of attachment common to animals whose inferior extremities are the chief means employed for quick and varied movement.

Coccygeal Vertebræ, 4 or 5.

The four or five coccygeal bones curve forwards from the inferior extremity of the pelvis. They are

* *Archetype and Homologies*, p. 159.

reduced to little more than the central element of a vertebra. The first piece is attached to the last bone of the sacrum by two cornua, which represent the neurapophyses, unconnected by a neural spine. The first coccygeal piece is often separate; the three succeeding ones are usually confluent, and form an elongated knotted cylinder.

THE HUMAN CRANUM is composed of four vertebræ, with neural and hæmal arches and appendages. The four neural arches surround the four primary subdivisions of the encephalon, namely, the cerebellum, the mesencephalon, or the nates and testes ; the cerebral hemispheres ; and the olfactory ganglia. The same succession of vertebræ is seen in the crania of other vertebrata ; but in man, owing to the highly-developed and expanded state of the cerebral hemispheres, the neural arches, or rings, are separated, and the sides of the cranium require the intercalation or introduction of other bones, which, in their typical condition, do not enter into their composition. A detailed account, however, of the cranium of the lower Vertebrata, though highly useful and instructive, would exceed the limits of this work.

The piece termed “ occipital bone ” represents the centrum and the neural arch of the occipital, or the first cranial vertebra ; the hæmal arch is completed by the triangular scapulæ (pleurapophyses), and by the coracoid processes (hæmapophyses). The clavicles are the hæmapophyses of the atlas, but are displaced that they may assist in affording support to the enormously developed coraco-scapular appendages, the anterior or the thoracic extremities.

The basi-occipital, a part of the “ basilar process ” of the occipital bone, is developed as a distinct piece from the basi-sphenoid in front, and from the ex-occipitals on either side. Superiorly it is concave

from side to side, and receives the cranial prolongation of the myelon, or spinal chord. The exoccipitals (neurapophyses) form the lateral boundaries of the foramen magnum, and are surmounted by the expanded neural spine, which, concave internally, is marked by four fossæ, the two superior for the posterior lobes of the backwardly extended cerebrum: the two inferior for the lateral lobes of the cerebellum. This expanded neural spine is formed from four centres of ossification, which unite at that prominent portion of the bone known as the occipital protuberance. Its superior border is prolonged forwards, as a projecting angle, between the two parietal bones, in the same way as the supraoccipital bone in the codfish is inserted between the parietals, and prolonged so as to articulate with the frontal bone. The rough ridge of bone extending outwards from the condyles, and called the jugular process, originally united to the basi-occipital by cartilage only, is the homologue of the paroccipital bone in the cod, turtle, &c., and is to be regarded as the parapophysis. There is a preparation in the museum of St. Bartholomew's Hospital, showing how closely the long transverse process of the atlas corresponds both in size and form with the parapophysial element of the occipital vertebra: between these two processes extends the rectus capitis lateralis muscle, a repetition, in serial homology, of the intertransversales muscles in the neck, and of the intercostales in the thorax. Be-

tween the basi-occipital and the paroccipital is the anterior condyloid foramen, which transmits the hypoglossal nerve.

The hæmal arch is formed by the scapulæ (pleur-apophyses) and by the coracoid processes (hæmapophyses) : there is no connecting hæmal spine, the shoulders with the upper extremities being thrown outwards, and maintained far apart by the strong cylindrical clavicles, which extend from the first bone of the sternum to the coracoid bone, and the acromion process. It may be here necessary to explain why the term "arch" is used in speaking of the homologies of the bones of the shoulder.

The displacement of bones from their typical position is often observed in the vertebrate skeleton, and is especially common in the disposition of the bones of the head. This displacement is the more frequently needed, because corresponding parts, limbs, or extremities, wherever they may be situated, are always developed from homologous bony elements. The pectoral fin, in fish, is most advantageously placed in immediate connection with the occipital bone at the base of the skull. In man it is removed to the upper part of the thorax ; but both limbs are, strictly speaking, homotypes ; and the connections of the pectoral fin are likewise the connections of the highly-developed arm, forearm, and hand. If we examine the vertebral column of the crocodile, we shall find not only lumbar, and dorsal ribs, but also cervical ribs, connected by suture only to the rest of

the bone. The parietal, frontal, and nasal vertebræ possess distinct hæmal arches. The occipital vertebræ is then only one to which an hæmal arch is needed. Reference to the skeleton of any fish will render this matter clear; for there the scapulocoracoid bones retain their typical position, and form a strong, well-marked arch, composed of the supra-scapular, the scapular, and the coracoid bones. The supra-scapula is composed of two short, cylindrical pieces, of which one is attached to the paroccipital, the other to the petrosal sense-capsule; they coalesce and form an expanded disc, from which the scapula, an elongated styliform bone, is suspended; from the extremity of the scapula proceeds the coracoid bone, which completes the arch by uniting, by ligament, with the corresponding bone of the opposite side. Arguing, then, from the class of fish, the earliest vertebrate inhabitants of this planet, we must refer the scapulæ and the coracoid bones to the occipital segment of the skull. The development of the former into a triangular plate of bone for the attachment of muscles, the confluence of the latter to form the coracoid process, and the separation of the two halves of the arch, that in man the movements of the right and left upper extremities, their free appendages, may not be impeded, must not blind us to the typical character of these bones. They are as much parts of the hæmal arch of the occipital bone as are the ribs, the costal cartilages,

and the segments of the sternum parts of the haemal arches of the dorsal vertebræ, to which they correspond.

The clavicles are the haemapophyses of the atlas : the haemal spine is confluent with the constricted centrum : the pleurapophyses are short and stunted. Let their homologues in the echidna or in birds be examined. Who can deny the strong resemblance between the furcular bone, and those wedge-shaped bones, which form the haemal canal for the protection of the artery which runs along the inferior surface of the caudal vertebræ in the kangaroo, the ferret, or the beaver ?

The second cranial vertebra (parietal) surrounds the mesencephalon, in which there is included part of the pons varolii, the optic lobes, or nates and testes, and the pituitary body : all these parts are covered in man by the highly-developed cerebral hemispheres. The basi-sphenoid (centrum) is that primitively distinct portion of the sphenoid bone, which lies between the basilar process of the occipital bone behind, the process olivaris of the sphenoid in front, and the two great alæ of the sphenoid on either side. The excavation for the pituitary body, and the prominent points of bone termed the posterior clinoid processes, give rise to the appearance, which, from its resemblance to an eastern saddle, has been designated *sella turcica*. The neuropophyses (alisphenoids) are represented by the great wings of the sphenoid bone. They soon coa-

lessee with the basi-sphenoid, and are perforated at their bases by the foramina (rotunda and ovalia) for the transmission of the second and third divisions of the trigeminal nerve.

The alisphenoids are pushed forwards from the occipital vertebra by the intercalation of the mastoid, squamosal, and petrosal bones, the coalesced assemblage of which constitutes the so-called temporal bone; but they maintain their connection with their proper neural spine (the two parietal bones), even in those skulls where the receding frontal bone would seem to push the parietals backwards towards the occiput.

The "temporal bone" of human anatomy is composed of the transverse process, or parapophysis of the parietal vertebra (the mastoid bone or process), of an appendage of the hæmal arch of the nasal vertebra (squamous bone), of the auditory sense capsule (petrous portion of temporal bone), of the pleurapophysis of the frontal vertebra (tympanic bone), and of the pleurapophysis of the parietal vertebra, or the styloid process. We will examine at present those elements only which are connected with the parietal segment.

The mastoid process (parapophysis) articulates by firm serrated suture with the posterior inferior angle of the parietal bone. It is nipple-shaped, rough externally for the attachment of muscles, excavated within into cells which communicate with the tympanum. Meckel, who incorrectly compares

the petrosal bone to the body of a vertebra, passes by the mastoid process without further remark, than that it is of conical form, and situated behind the styloid process. It receives the insertion of the trachelo-mastoid muscle, a slip of the longissimus dorsi, which extends longitudinally from the sacral diapophyses uninterruptedly to the parietal parapophysis, the only outstanding lever possessed by that cranial segment. It is curious to remark, that the squamous portion of the temporal bone, an appendage of the nasal vertebra, and intercalated only to complete the lateral walls of the expanded cranium, simply overlaps the parietal bone; whilst the mastoid, or parietal parapophyses, articulates with the same bone by serrated suture.

The styloid process, with its ligament (pleurapophysis), extends from the mastoid process (parapophysis) to the lesser cornua of the os hyoides (haemapophyses). The haemal arch is completed by the body of the os hyoides, or the haemal spine. The great cornua, or the thyro-hyal bones, the last remnant of the branchial arches in fish, extend backwards from the body of the os hyoides, or basi-hyal, and terminate in rounded points, which are connected inferiorly with the great cornua of the thyroid cartilage, by strong, and sometimes partially ossified ligaments: a broad membrane, thyro-hyal, connects the basi-hyal bone with the thyroid cartilage in the notch immediately above the union of

the two cartilaginous plates. These parts belong to the splanchno-skeleton.

The centrum of the frontal vertebra is represented by that primitively distinct portion of the sphenoid-bone, termed presphenoid; which, including the processus olivarum, lies anterior to the pituitary fossa, and between the alæ minores, or the processes of Ingrassias. Although the presphenoid may, in the full-grown foetus, be separated as a bony tubercle the size of a pea, from the basi-sphenoid behind it, Sœmmering describes the two as a single piece: “*Basis, sive continuatio partis basilaris occipitis crassissima est, et os ethmoideum tangit.*”* It is distinct from the processes of Ingrassias, or alisphe-noids, and united to the vomer, or the centrum of the nasal vertebra, by that form of articulation called Schyndylesis. Soon after birth it becomes confluent with the orbito-sphenoids, but it remains solid until the eighteenth year, when it is hollowed out to form the sphenoidal sinuses, two generally unequal cavities, separated by an irregular, and often imperfect septum. The sphenoidal sinuses are shut in below by two bones of the splanchnic skeleton, the cornua sphenoidalia, which, coalescing with the presphenoid and approaching in the mesial line, seem to give origin to the descending exogenous spine, the rostrum. It is by the cornua sphenoidalia that the union is effected between the

* *De corporis humani fabrica*, t. i., p. 107, cxx.

sphenoidal sinuses and the posterior division of the olfactory sense-capsule, the lateral masses of the ethmoid bone.

From the upper surface of the presphenoid the neurapophysis (processes of Ingrassis, orbito-sphenoids) take their rise. A median longitudinal ridge is prolonged forwards into a spine, which articulates with the cribriform plate of the æthmoid bone, at the base of the eminence termed crista galli. (On either side of this is a shallow groove, in which is lodged the commissural chords of fibrous and vesicular nervous matter, which connect the thin encephalic olfactory ganglia with the prosencephalon, or the cerebral hemispheres.) At the junction of the orbito-sphenoids with the presphenoid is the foramen opticum, directed forwards and outwards, and transmitting the optic nerve and the ophthalmic artery. The orbito-sphenoids are flattened and of triangular form, the apex directed outwards: the posterior internal angle projects over the pituitary fossa, and is named the anterior clinoid process: the internal carotid artery passes under it, sometimes through a complete ring of bone, as it emerges from the sphenoidal sinus to reach the base of the brain.

The thin anterior border of the orbito-sphenoids articulates with the frontal bone, their proper neural spine: the inferior surface is separated by an interval from the alisphenoids, or the neurapophyses of the preceding vertebra. The cranial walls, therefore, are imperfect in this situation, in the same manner

as if the ligamenta subflava were separated from the neurapophyses of any two adjoining trunk vertebræ : the fissure which results, termed sphenoidal, opens into the orbit, and transmits the third, fourth, ophthalmic division of the fifth, and the sixth nerves, filaments of the sympathetic nerve, and the ophthalmic vein : there is occasionally a small branch from the middle meningeal artery.

The neural arch is completed by the *os frontis*, the primitively divided halves of which are developed from single points of ossification, commencing immediately above the supra-orbital ridge. Meckel correctly described this bone as corresponding to the broad and expanded portion of the occipital bone ; but he went too far when he included in his comparison the “condyloid portions of the occiput” (ex-occipitals), which are serially homological with the orbito-sphenoids. In the ethmoidal fissure he recognised the repetition of the neural arches and of the foramen magnum. “We observe in the place corresponding to the large occipital foramen an analogous opening, which, however, is not closed behind, because the frontal bone has no basilar process. Perhaps this last is represented by the body of the sphenoid bone.”* The bone, divided into two portions, frontal and orbital, by the supra-orbital ridge, covers the front surface of the highly-developed cerebral hemispheres, which extend forwards and backwards so as to occupy the whole upper part of

* Meckel's Manual of Descriptive Anatomy.

the vault of the cranium. The smooth glabella separates the prominences, indicating the position of the frontal sinuses, which, formed by the separation of the outer and inner tables, communicate with the anterior ethmoidal cells, through which they open into the middle meatus of the nose. The two halves of the frontal bone, though usually confluent after the first few years, sometimes remain distinct through life, united by serrated suture, as are the two halves forming the parietal spine. The frontal plates form great part of the roof of the orbits: they are separated by a fissure (a continuation of the vertebral foramen of frontal vertebra) occupied by the olfactory sense capsule (ethmoidal cells), shut in by the cribriform lamella. The ethmoid bone, retracted in man under the projecting frontal spine, in connection with the relatively diminished proportion of the face to the head, will be described in conjunction with the nasal vertebra, with which it is intimately associated. The parapophyses, or the post frontals, are known in human anatomy by the name of external orbital processes, and are confluent with the rest of the bone at an early age. In the monkey, or in the sheep, they bring to mind more strongly than in man the distinct out-standing bones in the cranium of the crocodile. They articulate with the malar bone (or the haemapophysial appendage of the nasal vertebra), to assist in the completion of the firm ring of bone which encircles the orbit, and forms the external boundary of that fissure, between the supe-

rior maxillary bone (nasal hæmapophysis) and the base of the skull, termed spheno-maxillary.

The frontal pleurapophysis, or rib, is no longer the cylindrical bone observed in the cranium of serpents, or the chain of bones connected with the post frontals, which may be seen in the cranium of the codfish. It is represented by the thin ring of bone, called the external auditory process, which, though confluent in the adult skull, with the assemblage of elements constituting the "temporal bone," is developed from a distinct centre of ossification in the foetus. It is separated, as in Mammalia generally, from its own parapophysis (post-frontal) by the whole length of the temporal fossa: placed in front of the parietal parapophysis (mastoid), and pleurapophysis (styloid), it surrounds the meatus auditorius externus, and forms, in conjunction with the horizontal portion of the squamous bone, a concavity, which receives the articular extremity of its own hæmapophysis, the mandible, or the inferior maxilla.

The inferior maxilla, or the mandible, represents the hæmapophyses and the hæmal spine. The two halves of which it is composed become very soon confluent in the human subject, but remain longer distinct in the lower Mammalia. The different pieces composing the hæmapophysis in the mandible of the turtle or the crocodile may be traced in the single human bone. We recognise the articular bone, or the condyle, and the coronoid, or the pro-

cess to which is attached the tendon of the temporal muscle. In the foetal mandible there may be noticed upon the internal surface a thin and distinct plate of bone, which seems to shut in the sockets for the teeth, the splenial. The portion of bone which unites the two rami, and forms the symphysis, is the representative of the dentary bone or the haemal spine.

Three circumstances combine to render the study of the human nasal vertebra more difficult than that of the preceding. Firstly, it is retracted under the projecting frontal bone, or expanded spine of the frontal vertebra; secondly, the neurapophyses, hollowed out to receive the ethmoidal cells, are united in the mesial line to form the perpendicular lamella of the ethmoid bone, by which means their typical character is obscured; and, thirdly, the pleurapophysial and haemapophysial appendages, by their articulation with the rest of the skull, render this segment of the cranium rather complicated.

The centrum, or vomer, if examined in the foetal skull, is a long compressed bone, grooved upon its upper surface, to receive the flat triangular plate of bone, which subsequently coalesces with it, and unites it with the two nasal bones, or the divided nasal spine, forming a septum between the two lateral masses of the ethmoid bone. The neurapophyses (prefrontals) are represented by this flat triangular plate, known as the perpendicular lamella of the ethmoid bone. It is composed of two lateral

pieces, pressed side by side, so as to obliterate the neural arch: anteriorly they are prolonged by the nasal cartilage; posteriorly they send outwards, on either side, a thin plate of bone, which turns forwards, and assists, under the name of *os planum* of the ethmoid, to form a bony case, in which the loose spongy olfactory sense-capsule is lodged. In the crocodile the true characters of the perpendicular lamella, and of the *os plana*, may be recognized more easily than in the human skull: the olfactory sense-capsule, composed of cartilage, easily comes away from the two lateral concavities, which are still separated by the compressed neurapophyses, or ethmoidal septum.

The pleurapophyses (palate bones) articulate above with the *os plana* of the ethmoid, or the neurapophyses of their own vertebral segment. Projecting downwards, they terminate in a rough tuberosity, which articulates with the hæmapophyses, or the superior maxillary bones. The premaxillaries represent the divided hæmal spine. In cases of hare-lip, these distinct elements may be seen projecting forwards, with the incisor teeth, unconnected with the maxillary bones; the flat horizontally projecting palate plates articulate in the mesial line, and, from the forward direction of the hæmal arch (maxillaries), are brought into contact with the under surface of the nasal centrum (Vomer), which is prolonged forwards to constitute a septum, which divides the nares into two cavities.

The pleurapophysial appendage (pterygoid process) is coalesced with the basi-sphenoid, and for this reason the upper jaw is not movable as in birds; it is firmly fixed to the base of the cranium, by the ossification of the pterygoid appendages to the basi-sphenoid. The tuberosity of the compressed palate-bone (pleurapophysis) articulates in front with the maxillaries (haemapophysis), and behind with its own appendage (pterygoid). The confluence of the latter with the basi-sphenoid binds all these bones to the base of the skull, and renders the upper jaw immovable. In birds, the elongated palate-bones alone support their own pterygoid appendages, which lie by the sides of the basi-sphenoid, but wholly unconnected with them; the upper maxilla, therefore, may be pushed upwards, and the pterygoid appendages moved from the central position, by the mechanical pressure of the ossa communicantia (malar and squamous bones).

The haemapophysial appendages (malar and squamous bones) extend from the rough tuberosity on the outer surface of the maxilla to the tympanic and mastoid bones (elements of the temporal). Nowhere is the adaptation of type to special purposes better seen than in the changes of form which these haemapophysial appendages undergo in the vertebrate subkingdom. Broad and expanded in the turtle, they articulate with the post-frontals, the mastoid, and the tympanic bones, to form the arch which covers in the temporal fossa. Slender and

styliform in birds, they extend as the ossa communicantia from the tympanic bones to the upper jaw, which is by their pressure elevated when the mandible is depressed. They are broad and expanded in man, but for a different purpose than in the turtle; the malar bone articulates with the post-frontal, and forms part of the outer wall of the orbit, and it sends inwards a process which, uniting with the alisphenoids, completes the anterior boundary of the temporal fossa.

The squamosal appendage, inseparably coalesced with the other elements composing the temporal bone, commences anteriorly by a thin pedicle (zygomatic process) which articulates with the malar. It assists the tympanic in the formation of the glenoid fossa for the articulation of the lower jaw (frontal hæmapophysis); the remainder of the bone then spreads out into a flat scale, smooth externally, where it unites with the ali-sphenoid in front, and overlaps the parietal above; grooved internally, where it supports the ramifications of the middle meningeal artery, and forms part of the brain-case.

If vertical sections of the crania of the sheep, of the monkey, and of man be compared, it will be seen that, in the first, only the petrosal bone, or the auditory sense-capsule, makes its appearance in the cranial cavity, wedged in between the occipital and the parietal vertebrae; in the second, the squamosal bone is intercalated between the petrosal and the parietal, in the third is seen petrosal, squamo-



sal, and mastoid ; the latter deeply grooved for the terminal portion of the lateral sinus.

The proper interpretation of the meaning of the cranial bones has led to correcter views than were heretofore entertained of the relative importance of the different parts composing the encephalon. The common description of "the brain" throws no light upon the relations existing between the containing and the contained parts. All that we there learn is, that a mass of nervous matter occupies the brain-case, and overlaps a succession of ganglia, several of which are connected with the organs of special sense. Some of these parts are absolutely misnamed: as, for example, "the olfactory nerves," which in many animals are prolongations of the lateral ventricles, and even in man combine the necessary qualifications for a nervous centre, namely, the co-existence of white and of grey matter. They should be properly regarded as inter-cerebral commissures, which connect the olfactory ganglia with the cerebral hemispheres. The true olfactory nerves are those filaments which, invested in a neurilemma, pass through the cribriform plate of the ethmoid bone. Similar instances of incorrectness might be multiplied. In no department of science has greater light been thrown than in this, by the study of Comparative Anatomy. We learn that each of the four cranial vertebræ contains an encephalic segment similar to that which exists along the whole course of the neural canal. Although masked in man, by

the great development of the cerebral hemispheres, each maintains to some extent its typical connections. The cerebellum is contained in the occipital vertebra; the mesencephalon, comprising the pons varolii, the corpora quadrigemina, the pituitary body, and the space called the third ventricle, is surrounded by the parietal vertebra; the prosencephalon (cerebral hemispheres) lies in the frontal vertebra, and is continued in man both in the forward and backward direction; over the other encephalic ganglia, the rhinencephalon, or the fourth primary division, is represented by the olfactory ganglia: it rests upon the cribriform lamella of the ethmoid bone, and is connected to the prosencephalon by the chords of white and grey nervous matter, misnamed olfactory nerves. These segments of the encephalon are connected by commissures, both longitudinal and transverse. In man, the cerebral ganglia far exceed all the others in relative size; but in fish the ganglia are nearly equal, and succeed one another in linear series.

THE SERIAL HOMOLOGIES OF THE VERTEBRAL COLUMN.—In tracing the variations of form and relative size to which the centrum of a vertebra is subject, we may commence with the human coccyx; where the pieces, four or five in number, are reduced to their simplest condition. The terminal segment consists of a centrum only: it is a globular nodule of bone, rough posteriorly, but smooth anteriorly, where it forms the apex of the sacro-coccygeal concavity, in which are lodged the pelvic viscera. The two next segments are but little more complicated: two longitudinal ridges, with a shallow intervening groove, indicate some trace of neurapophyses, or laminæ, and of a neural canal. The first segment, or that which articulates with the sacrum, is flattened anteriorly, and supports posteriorly two backwardly extending neurapophyses, unconnected by a neural spine, but surmounted by zygapophyses, or surfaces for articulation with the sacrum. Two short diapophyses, of semi-lunar form, project outwards, and somewhat upwards on either side. The human coccygeal vertebrae, then, whose office consists in narrowing by their forward curve the antero-posterior diameter of the inferior outlet of the pelvis, are reduced to little more than the central element; but in other animals, and more especially in those supplied with long tails, the number of their component parts, as well as the absolute number, is much increased. In the human embryo the rudimental tail is longer than in

the adult, and the cartilaginous deposits indicate a greater number of caudal vertebræ than are persistent in the adult. In the ferret there are sixteen segments, of elongated cylindrical form, somewhat expanded at their extremities, to afford firm and broad surfaces for articulation. Many are supplied with zygapophyses or articulating processes, with strong projecting diapophyses, and with a hæmal arch to protect the long caudal artery. In birds, several of the terminal coccygeal bones coalesce into a single plough-share-shaped plate, smooth upon the sides, and compressed in the vertical direction. This coalescence of the inferior or terminal pieces of the coccyx is not uncommonly seen in the human subject. Specimens are numerous in which the coccyx consists of three segments: the terminal one composed of three centra, confluent, but somewhat constricted at the points of union; the middle one marked posteriorly by stunted neurapophyses, and united by cartilage to the first segment, which may be either articulated or firmly ossified to the extremity of the sacrum. The centra of five primitively distinct vertebræ unite about the sixteenth or seventeenth year to form the solid mass, termed the sacrum. It is with some surprise that we read the diffident way in which M. H. Cloquet expresses himself, in the earlier editions of his *Traité d'Anatomie*, upon this now well-established fact. "It is in consequence of this mode of development that many anatomists have considered the sacrum as

composed of the re-union of five vertebræ placed one above the other.”*

But with the centra there have coalesced the neur-apophyses and the neural spines, the zygapophyses, and the mass of bone which forms the outer boundary of the sacral foramina.

The special homologies of the iliac, pubic, and ischiatic bones will be mentioned in the description of the hæmal arch. The diapophyses posteriorly, and the stunted pleurapophyses anteriorly, which extend transversely outwards from the centra of the sacral vertebræ, become confluent about the seventeenth year, and nothing but the sacral foramina remain to represent the inter-diapophysial spaces behind, and inter-pleurapophysial spaces in front.

These points may be readily understood by the examination of the foetal pelvis, where the different vertebral segments remain distinct. In birds, whose wings require a fixed point of support whilst the body is elevated in flight, the confluence of the trunk vertebræ occupies a much larger region than in man. It extends from the pelvic through the lumbar region, and involves even the lower dorsal vertebræ with the pleurapophyses, or ribs.

The centra of the lumbar and of the dorsal vertebræ agree in all essential particulars; the former, broader than the latter, are inseparably united to their pleurapophyses, which form one mass with

* *Traité d'Anatomie descriptive*, p. 189, 1831.

the diapophyses. The prominent convex appearance which all these vertebrae present when viewed anteriorly, and contrasted with the cervical centra, is, in great measure, due to the absence of parapophyses, or the anterior elements of the transverse processes. In birds, the anterior surfaces of these centra present a prominent exogenous haemal spine, which divides the haemal surface of the vertebral column into two longitudinal halves, occupied by the powerful longus colli muscles. In the tortoise the centra of the succession of vertebrae supporting the shell, or carapace, are all united into a single long bone, as is the case with the sacral and lumbar vertebrae in the skeleton of the bird.

In many of the Mammalia the sacral vertebrae remain permanently distinct; such is the case in the beaver (*Castor fiber*), a creature that employs not only its long and powerful tail, but even the whole posterior half of the trunk, as an organ of propulsion through the water. In the chelonian reptiles, such as the turtles, the sacrum is usually composed of three vertebrae only; in ophidians, such as the snakes, and in fishes, it is impossible to divide the trunk into the regions familiar to us in the skeleton of man: the centra of all the vertebrae resemble one another, and remain permanently distinct. In the former we recognize a succession of the ball-and-socket articulation; in the latter, a series of bi-concave centra, united by means of an intervening jelly-like semifluid substance.

The centra of the cervical vertebræ, compressed from above downwards, have a flattened aspect anteriorly, in consequence of the presence of parapophyses, which spring from the sides of the centrum. The inferior margin is prolonged downwards, as an exogenous haemal spine, or tongue, over the centrum of the succeeding vertebra, in most of the cervical segments in man. The parapophysis, which exists in no other human trunk-vertebræ, is strongest in the upper cervical region, and gradually becomes thinner and narrower as it approaches the thorax. In the seventh cervical vertebra it is often a mere line of bone; occasionally it is absent. Very frequently the diapophysis and parapophysis of the seventh cervical vertebra are surmounted by a long pleurapophysis, which has been correctly recognised as a cervical rib. It does not remain distinct after the time when the vertebral segments are completed.

In consequence of man's erect posture, the centra of the four cranial vertebræ are brought from the vertical to the horizontal position, at a right angle to the spinal column, that the orbits, as well as the aperture of the mouth, may be directed forwards. In the foetus, at the full time, these centra may be clearly made out; the basi-occipital is united by cartilage to the basi-sphenoid, and the basi-sphenoid to the pre-sphenoid. The latter sends down an exogenous spine, which articulates with the vomer, or the centrum of the fourth cranial vertebra.

As in the pelvis, the haemal surface of the verte-

bræ is smooth and concave, to receive the blood-vessels and the viscera; so in the cranium the neural surfaces of the basi-occipital, the basi-sphenoid, and the pre-sphenoid, are excavated and smooth, to support the under surface of the encephalon. The vomer is a narrow, compressed bone, which requires a particular description.

The basi-occipital in the cod presents posteriorly the same concave surface which is seen in the vertebræ of the trunk; so also in reptiles the ball-and-socket joint of the spinal column is repeated in the articulation of a posteriorly-convex basi-occipital with the concave surface of the atlas.

The transition from the single convex occipital articulating surface in reptiles, to the double condyles in the cranium of man, is seen in the head of the crocodile and turtle. The single convex occipital condyle of the former is formed almost entirely of the centrum; two other processes from the exoccipitals complete the smooth rounded surface on either side. In the turtle a much larger portion of the occipital condyle is formed by the exoccipitals. In man the basi-occipital is bent forwards; the surface, which should articulate with the atlas, is thin, and forms the anterior margin of the foramen magnum. An oblong articulating convex surface, developed upon each of the exoccipitals, is received into a corresponding concavity in the lateral masses of the atlas, whose compressed centrum is unconnected with the cranium save by ligament.

The basi-sphenoid soon coalesces with the presphenoid, which is developed from a distinct point of ossification between the rings of bone forming, in the foetus, the optic foramina. The descending pterygoid processes are appendages of the haemal arch of the nasal vertebra. They extend backwards, maintaining their typical connection with the palate bones, and confluent with the basi-sphenoid, that the upper jaw may be immovably bound to the base of the skull. In most birds the upper beak moves slightly upwards when the mouth is opened ; and we find, in connection with this freedom of movement, that the palate bones and pterygoid processes are unattached to the prolonged cylindrical basi-sphenoid. An incorrect idea of the typical vomer would be formed from the examination of that bone in the human skeleton only ; in the cod-fish it is evidently a repetition of the cranial centra. Of elongated form, superiorly concave, thicker anteriorly than posteriorly, it supports the neurapophyses, which form the sides of the last neural arch in the head. In the turtle it assumes somewhat of the ploughshare form commonly seen in man : in the ostrich it is a thin concave plate of bone, which receives the prolonged extremity of the presphenoid. In the human foetus it somewhat resembles that which is seen in the ostrich ; but it is compressed laterally into a thin vertical plate, which assists in the formation of the septum nasi, with the descend-

ing plate of the ethmoid, and with the vertical nasal cartilage.

The neural arches of the coccygeal vertebræ in man are always incomplete. The neurapophyses of the first piece terminate in articulating processes, which in many instances coalesce with the sacrum: the succeeding vertebræ are marked by a superficial groove.

The confluence of the five sacral vertebræ reduces the neural canal to a continuous bony tube, which is bent, and with the concavity directed forward. There are usually no more than three or four neural spines; the last sacral vertebra being incomplete posteriorly, like the coccygeal vertebræ. The prominent ridge, lying to the outer side of the posterior sacral foramina, and running parallel to the neural spines, indicates the situation of the coalesced diapophyses and articulating processes. The greater part of the mass of bone external to this lateral ridge may be reduced to three or four pleurapophyses, or ribs, which, springing from the centra, incline backwards, and coalesce with the projecting diapophyses. That these parts should be properly understood, it is necessary to examine the sacrum of a full-grown foetus.

In the lumbar, dorsal, and cervical regions the neural arch is complete in every vertebral segment. That portion of the neurapophysis which springs from the centrum is constricted, or notched above and below, and forms with the contiguous vertebræ,

when *in situ*, the intervertebral foramen, or the opening for the passage of the spinal nerves. In the lumbar region the stunted pleurapophysis has coalesced with the root of the neurapophysis, and with the diapophysis, which, as in the lower dorsal region, has resolved itself into three heads: the epidia-
pophysis, internally; the extremity of the diapophysis, united with the pleurapophysis, externally; and the metapophysis mesially. In very many Mammalia the metapophysis is prolonged downwards to the outer side of the superior articulating process of the vertebra below, which is thus wedged in between two bony spines: in man, the metapophysis commences about the ninth or tenth dorsal vertebra, and disappears about the third lumbar. It affords attachment to the tendons of the longissimus dorsi muscle. The neural spines are, in great measure, formed by the confluence of the neurapophyses; but about the sixteenth or eighteenth year a thin plate of bone, developed upon their extremity, shuts up the otherwise open cancellous structure. Their direction is influenced by the amount of mobility in the different regions of the trunk. In the immovable dorsal region they are oblique, and imbricated; in the cervical and lumbar regions they are directed horizontally backwards. In the former of these regions the bifid spines indicate the union of the two neurapophyses: they are shorter than in the back, and connected together in the fresh subject by the elastic structure called the ligamentum nuchæ. The length

of the transverse processes of the atlas, and of the neural spine of the axis, is associated with the development of the small recti and obliqui capitis muscles, which are so intimately concerned in the movement of the head. These processes are particularly large in the lion and tiger; indeed, in all animals that use their jaws for seizing and lacerating their prey.

The neurapophyses (exoccipitals), and the neural spine (supra-occipital), of the first cranial vertebra, in man, offer a striking contrast to the narrow and compressed elements forming the neural arch of the atlas. But in the crocodile the spine of the atlas is nearly as broad and expanded as the occipital spine; and in the cod and the turtle the occipital spine preserves its compressed form, and is prolonged forwards, as a prominent ridge, between the two parietals.

The neural arch of the parietal vertebra is formed by the alisphenoids (alæ majores, sph. bone), (neurapophyses) and parietals (divided neural spine). The former are developed from points of ossification distinct from the basi-sphenoid and from the pterygoid processes, which are typical appendages of the nasal or the last cranial vertebra. At the time of birth these different elements are united by cartilage only. The divided spine is represented by the broad and concave parietals.

There is no part of a vertebra which undergoes greater varieties in shape and size than the neural

spine; it readily adapts itself to the highly-developed encephalon, and forms by far the greater part of the arch attached to the cranial vertebræ. The permanent separation of the two halves of the parietal spine is seen in fish, where the supra-occipital is prolonged forwards to articulate with the frontal bone. In the crocodile, the neural spines of the atlas, occipital, and parietal vertebræ are single flat bones, succeeding one another in linear series. In birds, and in the lower mammalia, the division between the two parietals, or the sagittal suture, becomes soon obliterated, and there results a single convex bone, which, however, always articulates by its extremities with the alisphenoids by a prolonged portion called the anterior inferior angle. The parietal parapophysis, or transverse process, is the mastoid bone, which in man forms part of that highly-complicated piece known as the temporal bone. It gives attachment by its extremity to the cranial prolongation of a muscle, connected to the diapophyses of all the trunk vertebræ, and known in its several regions by the names of longissimus dorsi, transversalis colli, and trachelo-mastoid. In the sheep it forms a strong outstanding process, wedged in between the paroccipitals and the tympanic bones. The presphenoid sends outwards the two thin and flat neurapophyses, called in human anatomy the processes of Ingrassias (lesser wings of the sphenoid bone). The neural arch is completed by the frontal bone (neural spine), which in many lower animals,

and occasionally in man, is formed of two separate halves united by a suture, continued forwards from the sagittal suture.

The neural arch of the nasal vertebra in man is obliterated, not from want of development of the neurapophyses, but from their being pressed together to form part of the septum nasi. They send outwards and forwards, however, two thin shells (*ossa plana*), which inclose the olfactory sense-capsule (or the cells of the ethmoid bone), and are prolonged upwards to articulate with the nasal bones, their proper neural spine.

The temporal bone, in man, is inserted between the occipital and parietal vertebrae, and forms an important ingredient in the construction of the cranial walls. It is formed by the confluence of five distinct bones. 1. Squamosal; 2. The mastoid; 3. The stylo-hyal; 4. The tympanic, or external auditory process; and, 5. the auditory sense capsule, or the petrosal bone. The special homologies of these different pieces have been already explained. All that it is necessary to mention here, consists in the fact that with the enlargement of the cranial neural arches, and their separation one from another, one or more of the abovenamed bones are introduced to fill up the vacuum. In the sheep no part of the temporal bone, except the petrosal sense capsule, is seen in the interior of the cranium. In many of the monkey tribe the squamosal likewise is intercalated, and extends so far forwards as nearly to separate the

alisphenoids from their spine (parietal bone). In man the petrosal and squamosal bones are united to the mastoid, which is hollowed out to receive the lateral sinus, and the three form a large and irregular surface, extending from the expanded parietals to the occipital and the post-sphenoidal centra.

The hæmal arch is absent in the human coccyx ; but it exists in the tails of many animals, where it is composed of hæmapophyses and a hæmal spine, the former slightly displaced, so as to articulate like the dorsal pleurapophyses, or ribs, with the contiguous borders of two vertebræ and their intervening fibrocartilage. In this canal runs the long caudal artery, protected by the bony arch from pressure, and giving off small transverse branches, the homotypes of the intercostals of the thorax, or abdomen, in its whole course.

In fish we notice a hæmal as well as a neural arch attached to the trunk vertebræ ; but it is formed, not by the hæmapophyses, but by parapophyses, which bend downwards, and, uniting inferiorly, form by their succession a long hæmal canal. The facility with which particular vertebral elements change their form or direction is one great reason why a new nomenclature has been introduced. It would be obviously a misapplication of terms to call these processes in the fish transverse when they curve downwards. Neither can they be called pleurapophyses, or ribs ; for these latter bones are attached in the upper thoracic region to the distal

extremities of the parapophyses, whose independency is thus established. Whilst engaged in the study of Homology the mind should never lose sight, in the first place, of the facility with which different vertebral elements may by some change of form be made subservient to the same functions; and in the second place, of the readiness with which the same element is converted into a variety of shapes, that it may effect some particular purpose in any of the different segments of the body.

The proper connections, and the typical significance of the bones called "ossa innominata," are obscured in man by their great expansion and early coalescence. They still, however, form a hæmal arch in which are lodged the coccygeal blood-vessels, the termination of the intestinal tube, the bladder and urethra, and the organs of generation. We have already seen that part of the solid sacrum, external to the anterior sacral foramina, represents the coalesced pleurapophyses of the sacral vertebrae. What, then, is the meaning of the three elements, ilium, ischium, and pubes, the assemblage of which constitutes an *os innominatum*?

Professor Owen, after shewing that the ilium, however expanded, belongs to one vertebral segment only, states that the hæmal arch, of which it forms a part, is open to two interpretations. The piece of bone confluent with the sacrum may be the whole pleurapophysis; the ilium, the hæmapophysis, and the pubes, the half of an expanded and bifid

hæmal spine; or the piece confluent with the sacrum, together with the ilium, may be two portions of a teleologically compound pleurapophysis; and the pubes the hæmapophysis, which would join with its fellow without or with a mere rudiment of a hæmal spine intervening. From the analogy of the scapulo-coracoid arch in fishes, which is proved by its modifications in higher animals to want the hæmal spine, it is most probable that such is the condition and true interpretation of the correspondingly simple pelvic arch under consideration.

The ischia are the hæmapophyses of the second sacral vertebra.

In the turtle the iliac bones, elongated and of cylindrical form, are attached superiorly to an outstanding process from one sacral vertebra only; from their distal extremity the broad pubic bones take their rise, and meet at the symphysis to complete the hæmal arch. The ossa ischii lie immediately posterior to the pubic bones, and the interval between the two constitutes the obturator foramen, which may be divided into two by a process of bone, or by a ligament extending backwards from the pubic to the ischiatic symphysis. In man the ossa ischii diverge to give passage to the urethra, but in many of the lower vertebrate animals their union is as close as the pubic symphysis. No better illustration of the typical character of the pelvic bones can be found than in the arrangement of the iliac, pubic, and ischiatic bones in the mole. They there form a

small hæmal arch, not very dissimilar in its general form from the succession of arches which protect the cocygeal artery in the tail of the ferret or of the kangaroo.

Of the seventeen vertebræ which intervene between the cervical region and the sacrum, twelve only, named dorsal, are in man supplied with a complete hæmal arch; the five inferior, named lumbar, have stunted pleurapophyses, which afford attachment by their extremities to the tendinous origin of the transversalis abdominis muscle. The completion of the hæmal arch in the lumbar region by soft and compressible, not by hard and unyielding, structures, is needed, that the abdominal walls may adapt themselves to the movements of the diaphragm, and maintain just the proper degree of compression upon the abdominal viscera. In animals that are prone, in whom the abdominal viscera require a greater amount of support than in man, the elongated and movable pleurapophyses are proportionately more numerous. In the dorsal region, the long, flat, and curved pleurapophyses articulate, by their proximal extremities, with the contiguous borders of two vertebræ and their intervening fibro-cartilage; by their distal extremities with the cartilages of the ribs, or the unossified hæmapophyses which unite with the chain of sternal bones or the hæmal spines, to complete the hæmal arch. The flat sternum of man, continued to the pubes by the tendinous linea alba, is represented, in the alligator,

by a chain of bones which extend in front of the abdomen, and support both lumbar and dorsal hæmapophyses. In birds there is the same rapid confluence of the different pieces composing the sternum as is observed in the development of the cranium ; but from the mesial line there projects a long and usually prominent plate of bone, formed of the coalesced hæmal spines, from either side of which arise the great pectoral muscles.

The hæmal arch is imperfect in the cervical region. The diverging parapophyses and diapophyses coalesce with a short pleurapophysis, concave superiorly, in man, to support the spinal nerves as they emerge from the intervertebral foramina behind the vertebral artery. None of the organs contained in the neck require the protection of a bony arch, which would interfere with the mobility requisite for the varied movements of the head. The only hæmapophyses typically belonging to the cervical vertebrae are the clavicles, which, displaced from the atlas, extend from the first bone of the sternum outwards to the equally displaced scapulo-coracoid arch of the occiput. The proper signification of the clavicles is seen in the furcular bone of the echidna, or of birds, where it forms a hæmal arch more complete than is effected by the distinct and separate clavicles of man.

Nowhere is the importance of homology more clearly exemplified than in the study of the attachments of muscles ; and perhaps, in illustration of

the truth of this statement, we may cite the muscles of the back, whose origins and insertions, as commonly described, may be considered as forming one of the most complicated and most unsatisfactory portions of Human Anatomy. The muscles of the back are either longitudinal or oblique ; that is, they either pass vertically downwards from spinous process to spinous process, from diapophysis to diapophysis, from rib to rib (pleurapophyses), &c. ; or, they extend obliquely from diapophysis to spine ; or, from diapophysis to pleurapophysis, &c.

The erector spinae is composed of two planes of longitudinal fibres, aggregated together, below, to form one mass at their point of origin, from the spines and posterior surface of the sacrum, from the sacro-iliac ligament, and from the posterior third of the iliac crest. It divides into two portions, the sacro-lumbalis, and the longissimus dorsi.

The former, arising from the iliac crest or from the pleurapophysis (rib) of the first sacral vertebra, is inserted by short flat tendons into (1.) the apices of the stunted lumbar ribs, close to the tendinous origins of the transversalis abdominis ; (2.) the angles of the eight or nine inferior dorsal ribs ; (3.) it is inserted, through the medium of the musculus accessorius, into the angles of the remaining superior ribs, and into the long and occasionally distinct pleurapophysial element of the seventh cervical vertebra ; and (4.) through the medium of the cervicalis ascendens, into the pleurapophysial elements of

the third, fourth, fifth, and sixth cervical vertebræ. In other words, the muscular fibres extend from rib to rib, from the sacrum to the third cervical vertebra.

The longissimus dorsi, situated nearer the spine than the sacro-lumbalis, is inserted, (1.) into the metapophysial spine of the lumbar diapophyses; (2.) into the diapophyses of all the dorsal vertebræ, near the origin of the levatores costarum; (3.) through the medium of the transversalis colli into the diapophyses of the second, third, fourth, fifth, and sixth cervical vertebræ, and (4.) through the medium of the trachelo-mastoid into the mastoid process, or the only element of a transverse process possessed by the parietal vertebra. In other words, its fibres extend from diapophysis to diapophysis, from the sacrum, upwards, to the parietal vertebra.

The proper connections of the occipital hæmal arch (scapulo-coracoid), can be better studied in fish than in warm-blooded animals, where it is displaced to the dorsal region. Cuvier seems to have entertained some doubt as to the propriety of comparing the pectoral extremity of fish with that of other vertebrate animals; “Comme le membre pectoral des poissons ne peut être comparé qu’ avec quelque doute à celui des autres animaux vertébrés, nous avons cru devoir en traiter particulièrement et dans son ensemble.*” But M. Dumeril, under whose revision the above quoted posthumous work

* *Leçons d'Anatomie comparée*, t. i. p. 366.

has appeared, speaks much more clearly as to the homologies of the scapulo-coracoid arch. "The pectoral fins are attached to a bony ring which surrounds the trunk behind the branchial apparatus, limits its orifice behind, and forms a kind of sill upon which the operculum strikes when it closes. This ring, when it is complete, is composed of three bones of each side, united by the squamous suture, or rather by imbrication, articulated to the posterior superior angle of the cranium, and descending under the throat to unite, most frequently by means of ligament, but sometimes by suture, with those of the opposite side. This apparatus can be regarded as the bones of the shoulder. Behind and below, there adhere to them two or three other bones, holding the place of the bones of the arm and forearm, and supporting the pectoral fin which represents the hand."*

The hæmal arch is again completed in the parietal vertebra by the styloid processes, the stylo-hyoid ligaments, the lesser cornua, and the body of the os hyoides, the latter sending back two long thyro-hyals (great cornua) which support the organ of voice or larynx and the succeeding rings of the trachea. The tenacity which the parietal pleurapophysis exhibits to affix itself to its proper vertebral segment is illustrated in the cranium of the ass, where the mastoid bone (parietal diapophysis) sends a process down between the tympanic bone and

* Op. Cit., p. 460.

the par-occipital to unite with the proximal extremity of the styloid process.

The special homologies of haemal arches of the frontal and nasal vertebræ, have been pointed out in the description of the cranial bones. The arch-like form of the inferior maxilla or the mandible will be recognized at once; that of the superior maxilla is obscured by the development of appendages, which bind the pleurapophysis (palate bone) to the base of the skull, and the haemapophysis (superior maxilla) to the cranial walls.

THE EXTREMITIES.—The simplest form of a diverging appendage is seen in the thorax of birds, from whose pleurapophyses, or ribs, there extend backwards short flat plates of bone, which overlap the external surface of the pleurapophysis, or rib, behind. The anterior and the posterior extremities are the highly-developed pleurapophysial appendages of the occipital and of the first sacral vertebræ ; the former retaining its typical connection in fish, but displaced in most Vertebrata, with its pleurapophysis and haemapophysis, to the upper dorsal region. In the flat diverging pectoral fin of the cod or the dolphin, we see a repetition of the diverging costal appendages of birds ; similar to them in shape and direction, but composed of the same primitive pieces, with the occasional exception of the humerus, as are noticed in the upper extremity of man.

The flat short bones of the upper extremity, in fish, become elongated in air-breathing Vertebrata in relation to the more varied and extended movements which they have to perform. The humerus, or the first bone of the appendage, is articulated to the pleurapophysis ; and the succeeding bones, increasing in number, acquire one with another a degree of mobility, less in extent, but more definite and certain in character. It is erroneous to connect with the word humerus the idea of a long straight cylindrical bone : in the turtle the humerus is S-shaped, and surmounted by its two tuberosities ; in

birds it is a long cylindrical bone, as in man ; in the mole it is expanded into a broad flat plate, twisted upon itself, and notched above and below for the transmission of arteries. In the same animal, the scapula, which we are in the habit of regarding as a flat bone, is elongated, and comes more under the head of a cylindrical bone than do any of the bones of the anterior extremity.

The five digits of the foot, in man, supported by their metatarsal bones, correspond with the digits of the hand. The great toe, which supports the chief weight of the body, has, like the thumb, two phalanges ; the other digits have three. But highly as both great toe and thumb are developed in man, they are the most inconstant elements of the extremities in *Vertebrata*. Dumeril, in a note appended to Cuvier's "*Leçons d'Anatomie Comparée*," has enunciated the law of disappearance of the digits in the different classes of animals. "That which we have seen in kangaroos authorises us in thinking that the two digits which remain in Ruminants are the third and the fourth ; thus the rule should be, that mammifers lose at first the thumb ; next the little finger ; next the index finger ; and, lastly, when there is but one complete, as in the horse, that this should be the middle finger."* The homologies of the bones of the extremities have long since been recognised by Meckel in his "*Descrip-*

* Note by M. Dumeril in Cuvier's *Traité d'Anatomie comparée*, t. i. p. 534.

tive Anatomy." "The bones of the upper and lower extremities correspond not only on the right and left sides, but also upward and downward; so that the lower limbs are a repetition of the upper, in respect to number and form, and the mutual relations of the different sections of which each limb is composed.

" Each is composed of four grand sections: the first is formed principally by one large bone; this is the scapular portion (*portio scapularis*) in the upper limb, and the iliac portion (*portio iliaca*) in the lower; the second includes one cylindrical bone, the humerus in the upper extremity, and the femur in the lower; in both, the longest and the next section is composed essentially of two bones, which are the radius and the ulna in the fore arm, and the tibia and the fibula in the leg; the fourth comprises, in the upper extremity the bones of the hand, and below, those of the foot, which correspond with each other almost perfectly in number, form, and divisions." A similar opinion had been previously entertained by Vicq-d'Azyr, who published a memoir upon the subject, but he revived the statement made by Aristotle, that the two extremities correspond in an inverse sense; that the right arm is repeated in the left leg, and vice versa. He compares the scapula with the ilium, the humerus with the femur, the two bones of the fore-arm with the two bones of the leg, the carpus with the tarsus, &c.; but in his particular determination he makes the fibula the homotype of the radius, and the tibia of

the ulna, an error which presented no small barrier against the establishment of the homotypes of the small wrist and ankle bones, and of their corresponding digits. “ L’Anatomie comparée, qui s’exerce sur différents individus qu’elle approche et qu’elle oppose l’un à l’autre, n’est pas la seule à laquelle l’observateur puisse se livrer ; il en est une autre qui mérite aussi son attention ; son sujet, quoique plus circonscrit, n’est pas moins curieux et moins philosophique : elle consiste dans l’examen des organes des mêmes individus comparés entr’ eux. C’est ainsi que les nerfs cervicaux peuvent être assimilés aux lombaires, les plexus axillaires aux sacrés, les nerfs diaphragmatiques aux nerfs obturateurs ; c’est ainsi que les extrémités supérieures et inférieures, observées dans la disposition des os, des muscles, des vaisseaux, et des nerfs, paroissent faites sur le même moule, mais placées en sens inverse par l’opposition de leurs saillies, et de leurs angles ; c’est ainsi que j’ai tiré de mes recherches le résultat paradoxal en apparence, mais susceptible de la démonstration la plus rigoureuse, que l’extrémité supérieure de l’homme, ou antérieure des quadrupèdes correspond, dans toutes ses points, à l’extrémité inférieure ou postérieure du côté opposé. La nature paroît donc un type ou modèle général, non seulement dans la structure des divers animaux, comme je l’ai déjà dit, mais encore dans celle de leurs différents organes.”*

* *Traité d’Anatomie et de Physiologie* par M. Vicq-d’Azyr, t. i., p. 11, 1786.

The ill-disguised contempt with which Cuvier regarded these opinions may be exemplified by the following passage, taken from his Lectures on Comparative Anatomy: "If the ossa ilii have any relation with the scapula, the other two pelvic bones are very badly represented; whether it be that the clavicle is taken for the pubis, or for the ischium, as would be inferred from the inverse position of the two extremities; *the trace of coracoid bone can hardly be taken into account.* The marsupial apparatus of the marsupiata is never reproduced at the shoulder; very often the clavicle is wanting; the coracoid bone is reduced to a mere nothing, whilst the pelvis retains its three bones well developed. The articulation of the leg on the thigh is very different from that of the fore-arm on the arm, because the movements have become so altered; for the same reason the tarsus has but a very incomplete resemblance with the carpus, and this resemblance, slight as it is, vanishes altogether in birds, not only between the tarsus and the carpus, but between all the rest of the extremity, because their mode of standing, on the one hand, and the nature of their flight, on the other, demanded the conditions which were proper to them. What, moreover, becomes of the law of repetition in the Cetacea, who, for a pelvis, have no more than a rudimentary pubis; in the lamartins, the dugongs, the sirens, the apodous fishes, in whom there does not remain a trace of it? Would the whole class of fish have been borrowed

for this speculation, if the comparison had commenced from thence ? a class in which the anterior extremity is so complicated, and the posterior so simple, or, by an arrangement quite contrary to that of other vertebrata, in which the anterior extremity is firmly fixed to the trunk, whilst the posterior is so often simply suspended in the flesh. One sees, on the other hand, quite clearly, the reason of this disposition peculiar to fish, in the preponderating part which the anterior extremity, the pectoral fin, takes in the movement of swimming. In investigating the resemblances of the extremities, one has not to do with merely a vain law of repetition which their differences sufficiently refute ; it is by this facility of generalising, without examination, propositions which are untrue but confined to a narrow circle, that it has been attempted to establish this law. These resemblances and differences are equally determined, not by the law of repetition, but by the grand and universal law of physiological concordance, and of the adaptation of means to an end."

Many of the objections here urged by M. Cuvier* have already been answered ; others seem rather unsatisfactory, coming from so accurate an observer, and so close and logical a reasoner. Why should the coracoid bone, stunted and coalesced with the scapula in man, be taken into less account than the fibula, stunted and coalesced to the tibia, or the ulna, stunted and coalesced to the radius in the horse,

* *Traité d'Anatomie comparée*, vol. i., p. 342, 1835.

or in the deer? The articulations of the knee and of the elbow bear a close resemblance to one another, and the homologies of the carpal and the tarsal bones can, without great difficulty, be determined. In the following table are arranged the homotypes of the bones forming the two extremities.

HOMOTYPES.

UPPER EXTREMITY.					LOWER EXTREMITY.	
Humerus	.	.	.	.	Femur.	
Radius	.	.	.	.	Tibia.	
Ulna	.	.	.	.	Fibula.	
Scaphoides	.	.	.	.	Naviculare.	
Semilunare	.	.	.	.	Astragalus.	
Cuneiforme	}	.	.	.	Os calcis.	
Pisiforme		.	.	.		
Trapezium	.	.	.	.	Int. cuneiforme.	
Trapezoides	.	.	.	.	Middle cuneiforme.	
Magnum	.	.	.	.	Ext. cuneiforme.	
Unciforme	.	.	.	.	Cuboides.	

A correct interpretation of the assemblage of bones forming the upper and the lower extremities depends in main part upon the determination of the true meaning of the scapulæ, clavicles, and the bones of the pelvis; and the obscurity in which the typical character of these bones is veiled in the higher vertebrata, by reason of their displacement, their extraordinary development, or their coalescence, is cleared away by reference to the skeleton of fish, or of the lowest reptiles, in whom the distinctive

characters of each segment are permanently retained. And it is with pleasure that we read the acquiescence which Cuvier, in his latter days, was beginning to yield to that view which established the homologies of the ring of bones arching downwards from the occipital bone in fish, and supporting the pectoral fin, with the scapula and the coracoid bones, in the rest of the vertebrate series. In a note appended to the article upon the Osteology of Fishes, the learned Editors of the "*Traité d'Anatomie comparée*," observe, "Some surprise will be excited that we give in this work, which bears the name of M. Cuvier, another determination of the bones of the shoulder and of the pelvis in fish than that which is found in his ichthyology; but in order to justify this apparent temerity let us say, that upon our communicating our ideas to M. Cuvier upon this subject a short time before his death, he replied, after having considered in all its bearings, and for more than a quarter of an hour, the skeleton of a fish placed before him, "Vous pourriez bien avoir raison," a common formula by which he gave his assent to any idea which was communicated to him."

The *os humeri* in man is an elongated cylindrical bone, surmounted superiorly by a convex head, directed obliquely upwards, inwards, and backwards, and separated from the shaft by a constricted neck. At the junction of the neck and the shaft are two tuberosities, between which is a groove, which re-

ceives the tendon of the biceps flexor cubiti muscle. The greater tuberosity, external and posterior, receives the insertions of the supra-spinatus, the infra-spinatus, and the teres minor muscles, upon distinct facettes of bone; the lesser tuberosity, placed internal and anterior, affords attachment to the tendon of the subscapularis.

Two prominent ridges, leading from the tuberosities to the shaft of the bone, upon which they are lost, mark the bicipital groove, and give attachment to muscles; on the anterior ridge is inserted the tendon of the pectoralis major; on the posterior those of the latissimus dorsi and the teres major. The outer surface of the bone, a little above its centre, is marked by a rough surface for the attachment of the deltoid muscle.

The bone becomes flattened and expanded laterally at its distal extremity, where two prominent lines lead to eminences situated upon its radial and ulnar side. The eminence upon the radial side (epicondyle) surmounts a convex surface of bone, the condyle, upon which rotates the cup-shaped head of the radius: the eminence upon the ulnar side (epitrochlea), larger and more prominent than the epicondyle, surmounts a pulley-like convex surface, the trochlea, which receives the articulating extremity of the ulna, and terminates in two fossæ, one anterior, to receive the coronoid process when the arm is flexed; one posterior, for the olecranon in extension. The os humeri, when viewed in its totality, appears twisted

upon itself; the flat distal extremity being curved forwards, whilst the inwardly directed head maintains its normal connection with the shaft. The hand, therefore, is supine instead of prone, as is the case with the foot; the pronator radii teres muscle is said to arise from the inner and not from the outer condyle, as does its homotype in the leg, the popliteus, &c.

The longitudinal measurement of the humerus seems to be in direct relation with the length of the metacarpal bones. "In animals supplied with a 'cannon bone,' it is covered by integument as far as the elbow; it is much elongated, proportionately to the whole body, in orangs, gibbons (long armed apes), bats, and sloths."* In bats, whose anterior extremity is used for striking the air in flight, the articulation of the *os humeri* with the scapula is a ginglymus or hinge joint, permitting nothing more than the upward and downward movement as seen in birds. No one who has confined his attention to human osteology would believe that the broad flat bone of the upper arm in the mole represents the long cylindrical *os humeri* in man.

In this animal it articulates not only with the glenoid cavity of the scapula, but also with the clavicle, by an articulating surface, which Cuvier regards as forming part of the greater tuberosity. The crista, from the lesser tuberosity, is so prominent, that it gives to the whole bone an irregular

* Cuvier, *Leçons d'Anatomie comparée*, vol. i., p. 383.

quadrilateral appearance, somewhat twisted, so that the ridge from the lesser tuberosity looks upwards. Of similar form and proportions is the *os humeri* of the echidna, the terrestrial monotreme of Australia ; a creature whose powers of rapid burrowing have excited the wonder of those who have witnessed its disappearance from pursuit by sinking directly downwards into the loose sandy soil over which it was attempting to escape.

The ulna, thicker at its humeral than at its carpal extremity, receives the pulley-like surface of the *os humeri* into a concavity, the greater sigmoid cavity, which is prolonged posteriorly by a rough quadrilateral process of bone, the olecranon ; and anteriorly by a pointed pyramidal eminence, the coronoid process. The plane in which the movement is effected, observes Cuvier, is in the axis of the ulna, and not in that of the *os humeri*, in consequence of the obliquity of the pulley ; whence it comes that in flexion the inferior extremity of the ulna is approximated to the body. Upon the radial side of the ulna, a shallow depression, the lesser sigmoid cavity receives the head of the radius. The shaft of the bone, marked by impressions for the attachment of muscles terminates in a rounded head, which is received into a concavity at the carpal extremity of the radius, and surmounted by a process termed styloid, to which is attached the external lateral ligament of the wrist joint. The radius presents at its humeral extremity a disc-like flattened head,

separated from the shaft by a constricted neck. The movement of rotation is performed in the joint between the convex border of the head of the radius and the lesser sigmoid cavity of the ulna. A prominent tubercle below the neck marks the attachment of the tendon of the biceps flexor cubiti. Below the bicipital tubercle the shaft of the bone curves outwards, and presents upon its convexity a rough surface for the insertion of the tendon of the pronator radii teres muscle. The broad flat inferior extremity, continued outwards into a styloid process, forms an articular surface for two of the carpal bones, the os scaphoides and the os semilunare. Upon the posterior surface are several grooves which lodge the tendons of the following muscles of the forearm. Proceeding from the radial to the ulnar side, 1. the extensor ossis metacarpi et primi internodii pollicis. 2. The extensor carpi radialis longior et brevior. 3. The extensor secundii internodii. 4. Extensor communis digitorum.

The objection which Cuvier raised to attempting the establishment of strict homologies between the bones of the thoracic and pelvic extremities, namely, "that the articulation of the leg upon the thigh is very different from that of the forearm upon the arm, because the movements have become so different," he himself answers in the following passage: after tracing the varieties in form in the bones of the forearm through the mammalian series, the position of the radius in front of the ulna

in the pachyderms (rhinoceros, tapir, &c.), the coalescence of the ulna to the radius, and the obliteration of the carpal extremity in the ruminants, the fixed prone position of the phalanges in the ruminants and solipedes, he adds, "We see from this series of conformations that the rotation of the hand becomes the more difficult, the less the animal uses it for prehension, and the more exclusively it employs its anterior extremity for support (station) and progression. In fact these last usages exact a constant pronation, and a firmness incompatible with the possibility of supination."* He might have added, they bring the anterior extremities to an arrangement of their component parts so similar to that of the posterior extremities, that their points of resemblance can be traced in every respect, but it must be remembered that the flexures of the knee and elbow are reversed; that which is flexion in the one is extension in the other, and *vice versâ*; but upon this point further remarks will be made after the consideration of the bones composing the knee-joint.

The carpal bones are usually described as eight in number, namely, scaphoides, semilunare, cuneiforme, pisiforme, trapezium, trapezoides, magnum, and unciforme. But the os scaphoides is composed of two primitively distinct bones; so likewise the os unciforme, which supports the two last metacarpal bones. Cuvier remarked that the carpus of monkeys has one bone more than that of man, and

* *Leçons d'Anatomie comparée*, vol. i., p. 408.

that it is situated between the scaphoid, trapezium, and os magnum, of which latter he incorrectly regarded it as a dismemberment. The os scaphoides is formed of two primitively distinct pieces, which, in the orang, “ extend almost as much from the os lunare as from the radius, along the radial side of the carpus to reach the trapezium and trapezoides ; it is in great part interposed between the lunare of the proximal row and the trapezium and trapezoid of the distal row of the carpal bones. The similarity of its connections in the carpus with those of the scaphoid in the tarsus is so close that the serial homology of the two bones is unmistakable.”* But the breadth of the human hand requires that the carpal bones should be arranged in two rows only ; consequently we find the two last bones coalesced to form the single os scaphoides, which, with the os semilunare, and os cuneiforme, constitute a convex articulating surface applied to the inferior extremity of the radius, and to the interarticular cartilage of the ulna. The os pisiforme projects from the os cuneiforme out of the line of the first range of carpal bones. The trapezium, the trapezoides, and the magnum support each a metacarpal bone. The os unciforme, to which are articulated the fourth and fifth metacarpal bones, is composed of two pieces, which in man are confluent at an early period.

The digits, supported upon their metacarpal bones, rarely exceed, in mammalia, the number of

* Owen on the Archetype Skeleton, p. 167.

ossicles contained in the distal row of the carpus. Though often reduced to one digit, as in the horse, the proper typical connections are never lost, though they may be, from many reasons, somewhat obscured. In man, the single piece representing the two first carpal bones, and called *os scaphoides*, articulates by a convex head with the trapezium and the trapezoides, the former supporting the thumb, the latter the forefinger. The semi-lunare, the *os magnum*, and the rays of the middle finger succeed one another in a straight line. The cuneiform and pisiform bones overhang the two ossicles, which, coalesced, form the *os unciforme*, upon which rest the two last digits, the ring and the little finger. The thumb, the most inconstant digit in mammalia, though the most highly developed in man, has but two phalanges appended to the metacarpal bone; all the other digits have three.

The *os femoris*, the longest bone in the human skeleton, is the homotype of the *os humeri*. Of cylindrical form, it is surmounted by a convex head, directed obliquely upwards, inwards, and a little forwards, and connected to the shaft by a long constricted neck, which appears inserted between two tuberosities, the greater and the lesser trochanter; the former affording attachment to the *glutaeus medius* and *minimus* muscles and to the external rotators of the thigh; the latter giving insertion to the conjoint tendon of the *psoas magnus* and the

iliacus internus muscles. From the trochanters, which are connected at the base of the neck by an anterior and a posterior intertrochanteric line, two ridges extend obliquely down the back surface of the bone to unite in a rough prominent ridge, the linea aspera, which separates at the inferior third of the femur into two lines, which, leaving between them a triangular space, pass, one to a tubercle situated upon the outer condyle, and the other to a tubercle situated upon and a little above the inner condyle. The smooth convex articulating surfaces of the condyles extend much further posteriorly than anteriorly: the anterior surface mounts higher upon the outer than upon the inner condyle, and it offers a broad expanse upon which the patella plays. The plane of the condyle is oblique, so that if the bone be placed upright upon a flat surface, the axis passes obliquely from without downwards and inwards. In many animals, *e. g.* the elephant, the rhinoceros, the plane of the condyles is even, and the weight of the animal is thrown upon a perfectly upright column of support. The os femoris is not twisted upon itself as is the os humeri, but it is curved, so that the anterior surface is convex and the posterior concave.

As Cuvier remarked, the length of the os femoris depends in general, in most classes of animals, upon the length of the metatarsus. In the horse it is much shorter than in the lion, where, instead of a long cannon bone, we find five distinct metatarsal

bones, supporting as many digits. In man the smooth articulating surface for the patella is continuous with that for the tibia; but in many animals (solipeds and ruminants for example) it forms a distinct articulating surface, and is more symmetrical in its extent over the outer and inner condyle. In man there is no trace of that bony prominence which in the beaver is continued from the linea aspera, and is called the third trochanter.

The tibia, the homotype of the radius, presents a broad and expanded head at its proximal extremity, where it is marked by two shallow depressions which receive the condyles of the femur. The shaft of the bone is triangular, and presents three smooth surfaces separated by rough or sharp lines. The anterior ridge is called the spine of the tibia, and gives attachment above to the ligamentum patellæ; the inner ridge gives attachment to the interosseous membrane, the fibres of which pass obliquely downwards and outwards to the fibula, as the fibres of the interosseous membrane of the forearm pass downwards and outwards from the radius to the ulna. The distal extremity of the ~~radius~~ is smooth and rounded, and terminates externally in the malleolus internus, the homologue of the styloid process of the radius. A concave pulley-like surface articulates below with the convex portion of the astragalus.

The tibia, unlike the radius, is firmly attached to the fibula, by a superior and an inferior articulating surface, but although the bone does not rotate upon

Tibia.

the fibula, as the radius does upon the ulna, both bones are, when flexed, susceptible of a considerable amount of rotation upon the femur.

The mistake, made by many anatomists, of comparing the ulna with the tibia, and of regarding the right arm as corresponding with the left leg, and *vice versâ*, arose from the absence in the human fibula of any process of bone which might be considered as a repetition of the olecranon; consequently, this latter process was compared to the patella, and the tibia, into which the ligamentum patellæ is inserted, became the homotype of the shaft of the ulna. Even Sœmmering and Meckel, usually so accurate, fall into this error. *Patella, maximum os sesamoideum, vel appendix tibiæ mobilis, olecrano nonnihil analoga videtur.** “The patella corresponds perfectly both in its situation and connection with this tendon, to the olecranon process of the ulna; and hence the tibia has no process which may be compared with the olecranon. The patella increases the analogy between the bones of the leg and those of the forearm.”†

But reference to the skeleton of the echidna will shew, that upon the upper extremity of the fibula there may be developed a process equally long, and of similar shape with the olecranon process of the ulna; and this, too, in a limb supplied with a patella imbedded in the common extensor muscle of

* Sœmmering de Ossibus, t. i. p. 385.

† Meckel's Anatomie Descriptive : Art. Patella.

the leg. Professor Owen, who calls this fibular lever the fibella, is the first, I believe, who has pointed out the true homologies of this part of the skeleton. The fibella in the human skeleton, though stunted, is prolonged upwards upon the posterior part of the tibia, in the form of a slight elevation or tubercle. This stunted fibella is noticed by Hildebrandt in his description of the fibula:—
“Das obere ende des wadenbeins, welches ungefähr dreikantig ist und der kopf, caput oder capitulum des wadenbeins heisst, hat nach hinten und aussen eine stumpfe spitze.”*

But he omits to draw from thence the proper homological inference as to the true signification of the fibula; or to point out that with the prone position of the foot must correspond the prone position of the hand, the great toe and the thumb being both situated nearest to the mesial line of the body. If the upper extremity be placed in this, its true typical position, it will be seen that the radial side of the arm should be properly called internal, and the ulnar side external, just as the tibial side of the leg is called internal, and the fibular side external. The determination of these points is absolutely indispensable before attempting to trace the homologies either of the small bones of the hand and foot, or of the muscles which act upon the extremities.

The fibula is of irregularly triangular shape, and

* Hildebrandt's anatomie, b. ii., § 264.

presents three surfaces, and three borders. To the inner border, or ridge, is attached the interosseous membrane, the fibres of which pursue a precisely analogous direction with the fibres of the interosseous membrane in the forearm; *i. e.*, they pass obliquely downwards from the tibia to the fibula, from within outwards. The surfaces, to which the muscles which act upon the foot are attached, correspond but imperfectly with the surfaces upon the ulna, yet the fibula can hardly be regarded as twisted upon itself, as stated by Meckel. The external malleolus looks inwards, as does the styloid process of the ulna, and maintains its proper relative position with the eminences upon the head of the bone.

The typical number of the tarsal bones corresponds with that noticed in the carpus. The seven bones described in the human tarsus represent ten primitively distinct ossicles. The single piece, called *os naviculare*, or *scaphoides*, is composed of two bones, which answer to the compound *os scaphoides* of the carpus; the *astragalus* is the *semilunare*; the *os calcis* is the *cuneiforme* and the *pisiforme* combined. The internal *cuneiform* supporting the *metatarsal* bone of the great toe repeats the *trapezium*; the middle *cuneiform*, the *os trapezoides*; the external *cuneiform*, the *os magnum*. The *os cuboides* corresponds with the *os unciforme*: formed by the coalescence of two distinct ossicles, it articulates behind with that portion of the *os calcis* which is

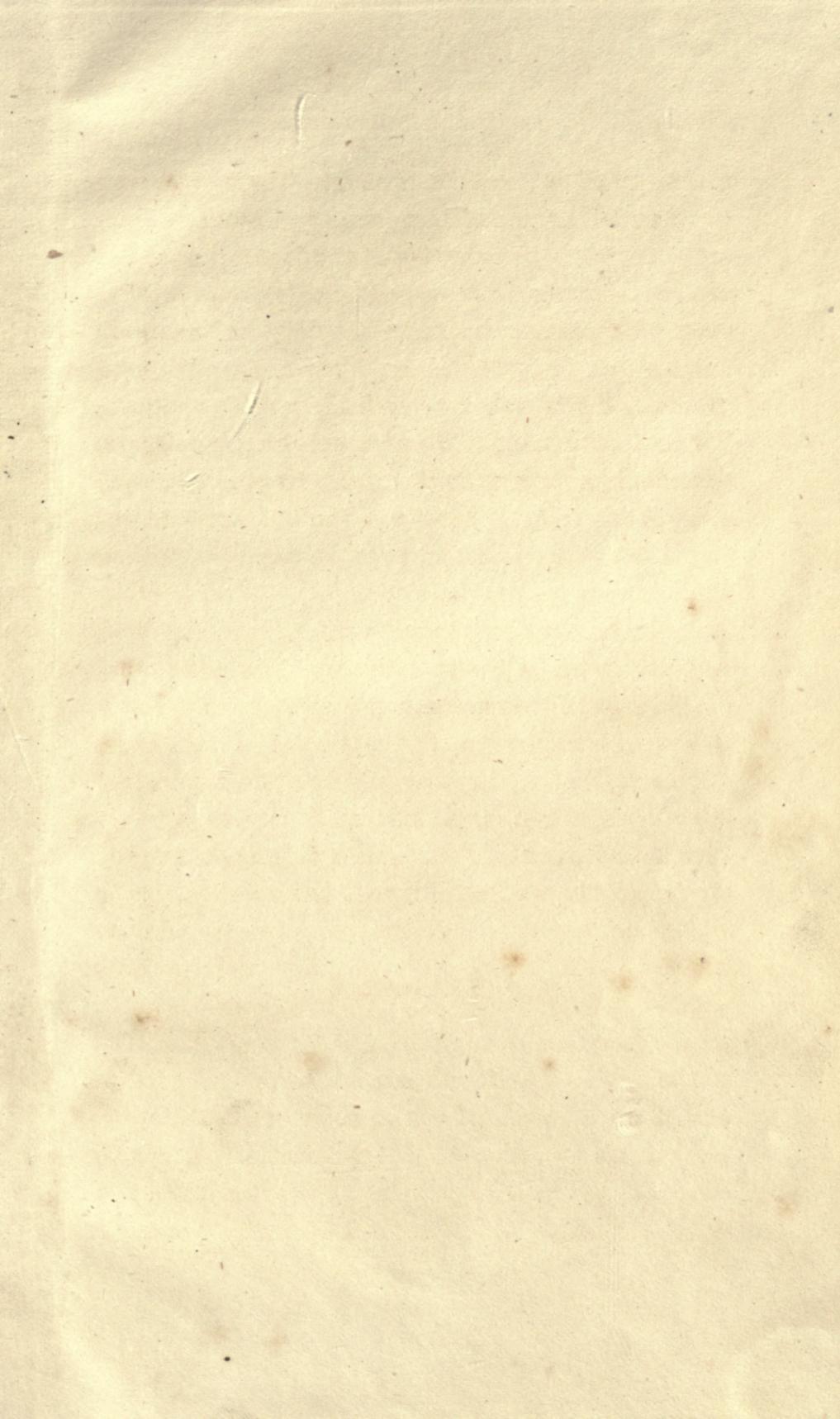
homologous with the *os cuneiforme*, and supports in front the two last metatarsal bones, as the *os unciforme* supports the two last metacarpals.

In most vertebrata the foot is longer and narrower than the hand, which is constructed more for purposes of prehension than of progression. We are not therefore surprised to find that the first row of tarsal bones, unlike those of the carpus, lose the horizontal and transverse arrangement, and are subject to more frequent coalescence. One bone only, the *astragalus*, receives from the bones of the leg, the weight of the body. The primitively compound *os scaphoides* receives its anterior rounded extremity, and, removed to the inner border of the foot is interposed between this convex head and the three *cuneiforme* bones. The two homologues of the *cuneiform* and *pisiform* bones of the carpus coalesce to constitute the *os calcis*; into which is inserted the *tendo Achillis*. There can be no need of pointing out the reason why these two bones are not distinct, as in the carpus. A small movable *os pisiforme* is a sufficiently firm point of insertion for the flexor muscle of the wrist, but would be wholly inadequate as a powerful lever of sufficient strength, when elevated, to sustain the whole weight of the body. The reception of the head of the *astragalus* into a cup formed by the *os calcis*, *os scaphoides*, and the elastic *calcaneo-scaphoid* ligament constitutes one of the most important modifications in the articulation of the tarsal bones. The sudden shock,

which would be communicated to the body, when the feet strike the ground in jumping, running, &c., is by this means avoided, or at least rendered milder; and to its elastic properties may be referred that springiness, and light step, which so distinguishes the progressive movements of the young from those of the old or infirm.

The three cuneiform, and the cuboid bones bear a striking resemblance in their arrangement and connections with the second row of the carpal bones, and much more stress would have been laid in earlier works of Anatomy upon this point, had the error been avoided of comparing the patella with the olecranon. But the necessity which in that case followed, of making the tibial side of the leg correspond with the ulnar side of the forearm, exacted a second necessity of comparing the great toe with the little finger instead of with the thumb. The consequence of thus confounding the outer and the inner side of a limb was to reduce the matter to a state of inextricable confusion. The firmness of both the hand and the foot requires that the two small external digits, less movable than the rest, should be supported upon a solid single piece, which in the carpus is opposed to the *os cuneiforme*; and, in the tarsus, to the homotype of the *os cuneiforme*, viz. the anterior portion of the *os calcis*.

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